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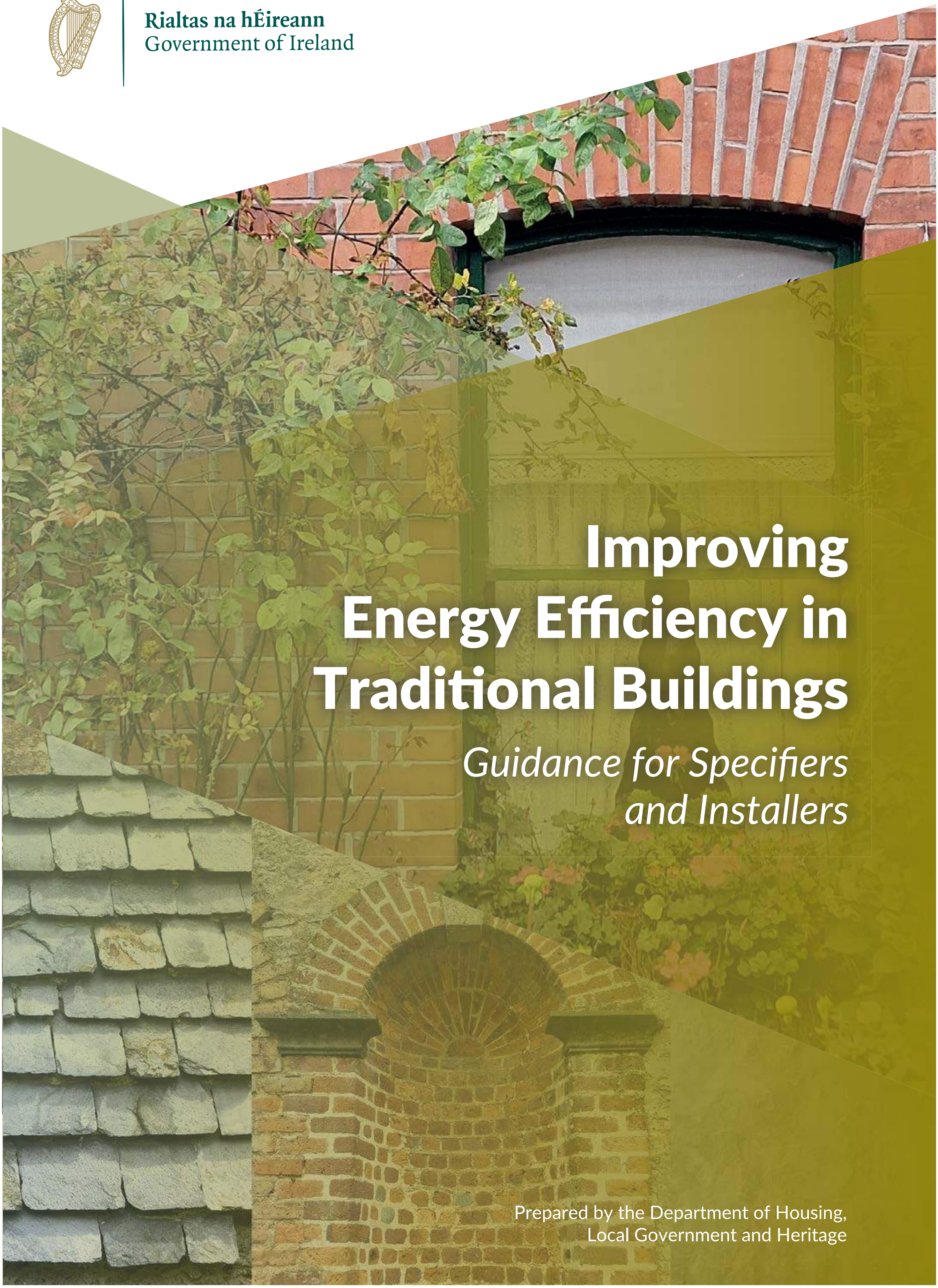


Improving Energy Efficiency in Traditional Buildings

Guidance for Specifiers and Installers

Prepared by the Department of Housing, Local Government and Heritage

The Department of Housing, Local Government and Heritage accepts no liability for any loss or damage resulting from reliance on the advice contained in this publication. The sketches in this publication have been developed to support the application of Part L of the Building Regulations to traditional buildings and to ensure good conservation practice, as appropriate. They are indicative, not prescriptive, and focus primarily on issues of thermal performance, ventilation and airtightness. Other issues are not considered fully in these drawings. Insulation thicknesses for the main building elements have not been provided, as these depend on the thermal and hydrothermal properties of the insulation material chosen, as well as on the desired U-value. All materials and workmanship should be provided in accordance with Technical Guidance Document D 'Materials and Workmanship' and relevant Irish Agrément Board certificates.

All images are by the contract team or DHLGH except where otherwise stated. The sketches were drawn by Shaffrey Architects.

Contents

Foreword

Traditional buildings form the core of our cities and towns and populate our countryside. They can be landmark buildings of high cultural significance, simple single dwellings or any building type in between. Their continued existence as the backdrop to our everyday lives plays a key role in our cultural heritage, our identity and our sense of place.

Many traditional buildings are protected structures or are located in architectural conservation areas. However, the vast majority of traditional buildings do not have statutory protection. Nonetheless, they all need careful consideration in any energy-efficiency upgrading to avoid unintended, and potentially damaging, consequences. This guidance promotes a whole-building approach to ensure that the energy-efficiency measures adopted are suitable, robust and sustainable.

Ireland has set ambitious targets to reach to reduce greenhouse-gas emissions and meet international commitments on climate change mitigation. Improving energy efficiency in the traditional building stock is key to meeting these commitments. While the emphasis on the energy retrofit of buildings is important, the integrity of our traditional buildings needs to be respected when changes are being made. The energy performance of most of our historic and traditional buildings can be improved, helping them continue to be viable, both now and into the future. We want to keep our traditional buildings in use and allow them to continue to provide comfortable, safe and beautiful places to live and work. We also want to prove that they have a substantial role to play in addressing the climate crisis.

Darragh O'Brien TD
Minister for Housing,
Local Government and Heritage

Malcolm Noonan TD
Minister of State for Nature,
Heritage and Electoral Reform

Chapter 1

Context

This chapter contains:

- an explanation of a 'traditional building' in the Irish context and the types of buildings considered within this document
- the statutory requirements pertaining to the alteration of traditional buildings
- an explanation of the Building Energy Rating system and its application to traditional buildings
- recommendations for professional skills and services that may be required on different retrofit projects
- information on the full environmental impact of construction, including embodied carbon
- information on step-by-step retrofits and Building Renovation Passports

1.1 Introduction

The Climate Action Plan sets out policies and measures across all sectors to tackle the climate emergency. This includes an objective to upgrade 500,000 homes to a B2 Building Energy Rating (BER) or cost-optimal[1] or carbon-dioxide equivalent by 2030. There are also targets for upgrading non-residential buildings.

Ireland is required under the Energy Efficiency Directive (EED) to reduce energy demand significantly by 2030. In order for the EED target to be met, Ireland must reduce national energy use by approximately 20% compared to 2019. Ireland also has challenging targets to achieve for greenhouse-gas (GHG) emissions reductions. Improving the energy efficiency of buildings plays a crucial role in achieving these important goals in addition to reducing energy waste and energy bills and improving energy security.

Often the energy performance targets set for new construction pose particular difficulties for older buildings that may be of architectural or historical interest, including buildings of traditional construction with vapour-permeable fabric. However, many opportunities exist to significantly improve the energy performance of these buildings, reduce GHG emissions and enhance the comfort of users.

This guidance sets out approaches on how the energy upgrading of traditional buildings can be achieved in appropriate ways. The aim should be to improve energy efficiency as far as is reasonably practicable, taking care not to prejudice the character of the building or increase the risk of long-term deterioration of the building fabric.

1.2 What Is a 'Traditional Building'?

Traditional buildings in Ireland generally include those built with solid masonry walls of brick, stone or clay, using lime-based mortars, often with a lime or earthen-based render finish, single-glazed timber or metal-framed windows and a timber-framed roof usually clad with slate but often with tiles, copper, lead or, less commonly, corrugated iron or thatch. In general, these were the dominant forms of building construction from medieval times until the second quarter of the twentieth century.

The primary difference between traditional and modern construction is in the way moisture is managed in the external walls. Traditional materials and construction techniques allow for the natural transfer of heat and moisture. Solid masonry walls therefore relied on their thickness to cope with atmospheric moisture, being sufficiently thick to ensure that drying out took place before external moisture reached the inner face of the wall. External lime renders were sometimes used as a weathering coat to reduce the amount of moisture being absorbed by the walls without trapping interstitial moisture, i.e. moisture occurring within the thickness of the wall. Many traditional buildings in Ireland were built in this manner and it is therefore essential that all materials and finishes, including mortars, renders and plasters, used on traditional walls are vapour-permeable materials that both absorb and readily allow the evaporation of moisture. A selection of typical traditional wall build-ups is shown in Figure 1, but it should be noted that this is not a definitive list. Variations in materials, construction and thicknesses are to be expected.

[1] Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings (recast), Article 2

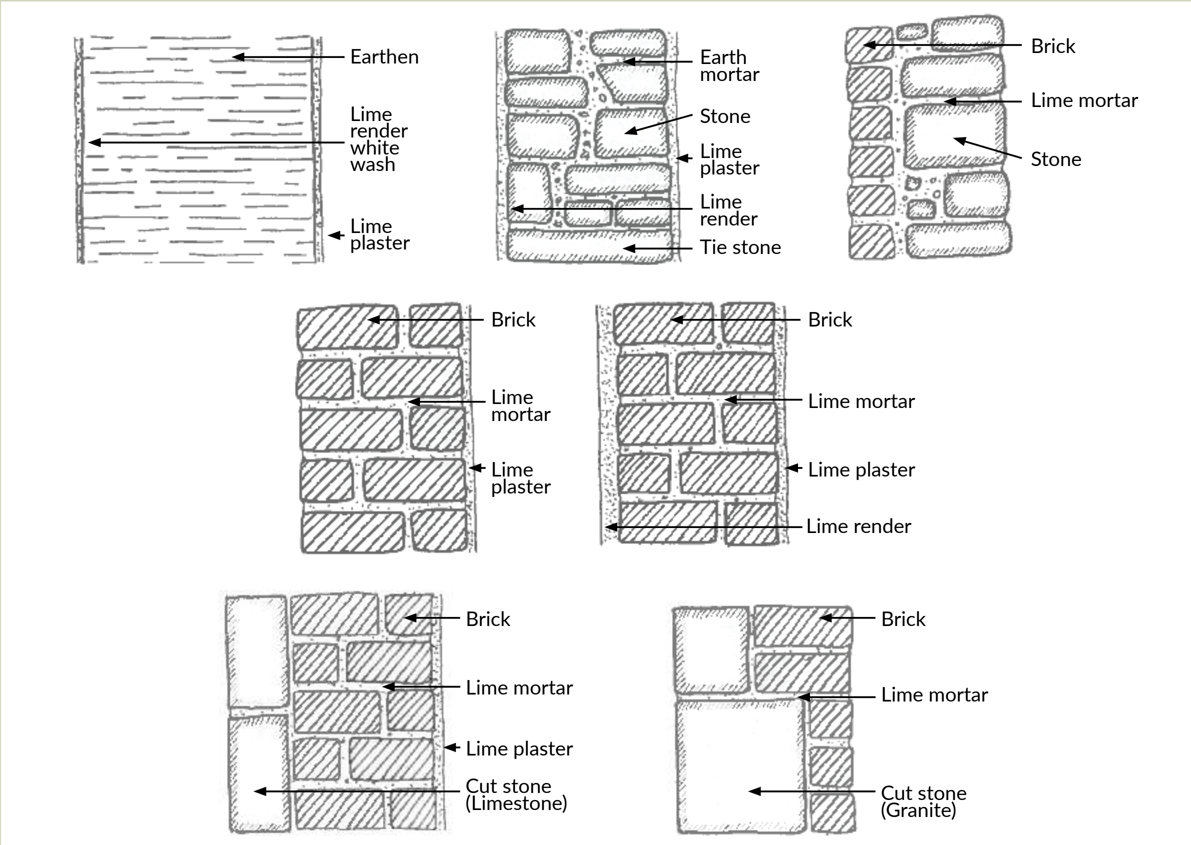


Figure 1: Illustrative examples of different types of traditional masonry walls and their typical build-up

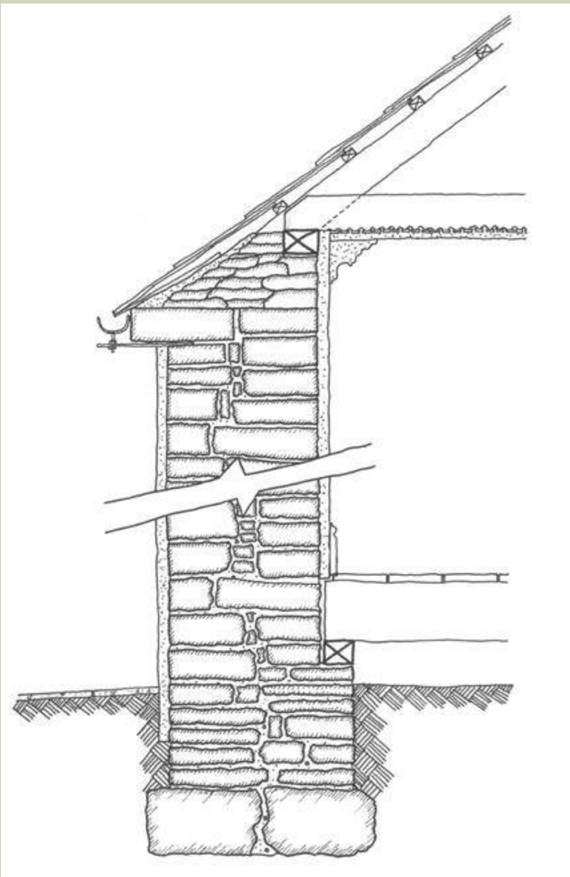


Figure 2: Typical solid masonry wall

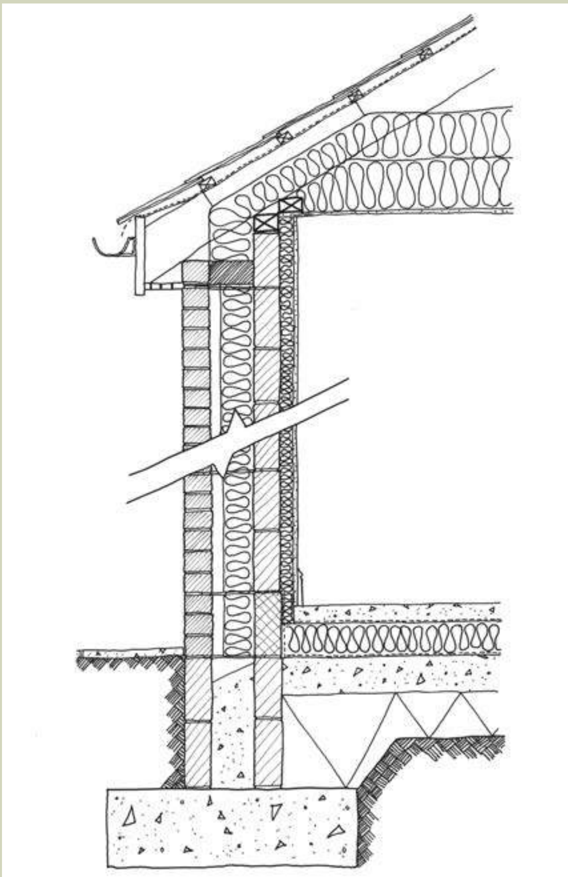


Figure 3: Typical modern cavity wall

Modern construction is largely distinguished by the use of more vapour-impermeable materials as well as the development and widespread use of twin-leafed construction, commonly called the cavity wall. Cavity walls consist of an outer leaf, which is presumed always to be wet, and an inner leaf, which should always be dry, with the air-filled cavity acting as a water barrier. In the earliest cavity wall constructions, the cavity was left empty. Latterly, it was either partially or totally filled with an insulating material. Simply put, modern construction is generally designed to keep moisture out through the use of air cavities or vapour-impermeable materials and layers, which is different to the management of moisture through the wetting-and-drying cycles associated with traditional vapour-permeable construction (see Section 2.1.2 below for more detail on moisture movement in traditional buildings).

According to the 2016 census records, 9% of all private homes in Ireland were constructed prior to 1919 and 7% were constructed between 1919 and 1945. Most of these were of solid masonry, traditional construction. However, some early examples of modern construction can be found within this period. For instance, many local authority dwellings built after 1922 were constructed with solid, mass-concrete walls which are typically thinner than solid masonry walls.

A skilled conservation consultant should be able to make an educated guess on the make-up of a wall based on research of the architectural style, construction techniques and historic resources such as architectural drawings and publications, combined with a knowledge of local building traditions and their development over time. Ordnance Survey maps and other cartographic records can also assist in determining the period of construction. However, the only definitive way to know the build-up of a particular wall is to remove a patch of the render and/or plaster and take a core sample.

The guidance in this document deals with the energy upgrading of traditional construction only. Guidance on the upgrading of modern construction, including early solid concrete walls and early twin-leafed or cavity wall construction, can be found in S.R. 54:2014&A2:2022 Code of Practice for the Energy Efficient Retrofit of Dwellings.

Stylistically, traditional buildings in Ireland vary widely, and include vernacular or architect-designed residential, industrial, commercial and institutional buildings. Ireland also has a rich legacy of solid-walled medieval structures, many of which remain in use as habitable buildings. It should be noted that while some traditional buildings are protected structures or proposed protected structures, or are located within architectural conservation areas (ACAs), the majority are not. Care must still be taken with non-protected traditional buildings as energy-efficiency upgrades can adversely affect the character or the fabric of these buildings if incorrectly implemented.

Note: Earthen walls and thatched roofs are generally not covered in this document, noting that these materials often have good thermal performance and as such, present limited opportunity for thermal upgrade. Actions under the Department of Housing, Local Government and Heritage's Vernacular Strategy[2] aim to provide further information on the options available for upgrading these building typologies.

[2] Government of Ireland (2021a)

Conservation Principles[3]

Conservation is the process of caring for buildings and places and managing change to them in such a way as to retain their character and special interest. It involves retaining and preserving the authentic materials and craftsmanship of the building and its elements while allowing the building to evolve and adapt to meet changing needs. Historic structures are a unique resource. Once lost, they cannot be replaced and if their special qualities are degraded, these can rarely be recaptured.

Many of these buildings have already survived for decades, if not hundreds of years, with each generation adding its own layer to a unique history. It is the responsibility of the current generation to hand them on in good condition to allow future generations to enjoy them too.

So that the works undertaken do not damage the character and special interest of a historic building,[4] it is important to understand some of the basic principles of good building conservation. Many of these are common sense and all are based on an understanding of how historic and traditional buildings work and how, with sensitive treatment, they can remain special.

Dos and don'ts of carrying out energy upgrading works:
Do balance the need to conserve energy with minimising impacts on the historic building fabric. Identify how and where change can occur and ensure that the fabric and the character of the building will not be damaged by inappropriate intervention.
Do ensure that the building is in good repair before carrying out upgrading works.
Do use the experts where necessary and get independent advice from competent people.
Do research the historical development of the building and understand thoroughly its current condition before making decisions. Later alterations may be important, and evidence that the building has been cared for and adapted over many years. Some alterations, however, may have damaged the building's appearance or the way in which it functions. If so, such alterations should be reversed whenever possible without causing further damage.
Do repair the parts of the building that need it; do not replace them unless they can no longer do the job they were designed to do. Not only does this preserve the authentic historic fabric of the building, it also minimises or avoids unnecessary waste.
Do make sure the correct materials and techniques are used and that even the smallest changes to the building are done well. If introducing new, non-traditional materials, ensure that these are compatible with traditional building fabric.
Do use techniques that can be easily reversed or undone. This allows for any unforeseen problems to be corrected in future without damage to the character and special interest of the building
Do record all works for the benefit of future owners and occupants
Don't push the building beyond what is reasonable to expect and only do as much work to the building as is necessary, and as little as possible.[5]
Don't consider upgrading works in isolation: consider them in the context of the building as a whole.
Don't use architectural salvage from elsewhere unless certain that the taking of the materials has not caused the destruction of other old buildings or been the result of theft.

[3] Government of Ireland (2011), particularly Chapter 7, 'Conservation Principles'

[4] I.S EN 16883:2017, Article 3.1.10 defines a historic building as a building of heritage significance. A historic building does not necessarily have to be statutorily designated as cultural heritage

[5] ICOMOS (2013) Article 3

1.3 Complying with Statutory Requirements

When considering energy-efficiency upgrading, one should be cognisant of the statutory obligations that may apply, such as planning legislation, national monument legislation, wildlife legislation, building control legislation and building regulations.

1.3.1 Planning and Development Acts[6]

Under the Planning and Development Act 2000 (as amended), development includes the carrying out of works (for example, construction, demolition, alteration) on, in, over or under land, or the making of any material change of use of any structures or other land. Generally, planning permission is required for any development of land or property unless the development is specifically exempted.

Exempted developments are set out in the Planning and Development Regulations 2001 (as amended). Exemptions exist to avoid restrictions on minor developments. Planning Leaflet 3 from the Office of the Planning Regulator outlines the steps in the planning process, providing answers to common questions.

Works to the exterior of any building cannot be considered exempted development unless they do not materially affect the external appearance of the structure so as to render the appearance inconsistent with the character of the structure or of neighbouring structures.[7] Early consultation with the planning authority is advised. Examples of works that could potentially require planning permission include:

- the application of external insulation
- the replacement of windows and doors.

To determine what, in any particular case, is or is not development or is or is not exempted development, anyone may write to the relevant planning authority under Section 5 of the Act requesting a declaration on that question, providing any information necessary to enable the authority to make its decision on the matter.[8]

1.3.1.1 Architectural Heritage

Part IV of the Planning and Development Act 2000 (as amended) sets out the legislative provisions for the protection of architectural heritage. Detailed guidance on protected structures, proposed protected structures and architectural conservation areas can be found in the statutory guidelines *Architectural Heritage Protection: Guidelines for Planning Authorities*.[9]

It is important to note that where a structure is included in the record of protected structures (RPS), is proposed for inclusion, or is located within an ACA, the usual exemptions for planning permission may not apply.

1.3.1.2 Protected Structures and Proposed Protected Structures

A protected structure is defined as any structure or specified part of a structure that is included in the RPS of the planning authority. A structure is defined as any building, structure, excavation, or other thing constructed or made on, in or under any land, or any part of a structure. In relation to a protected structure or proposed protected structure, the meaning of the term ‘structure’ is expanded to include:

a) the interior of the structure
b) the land lying within the curtilage of the structure
c) any other structures lying within that curtilage and their interiors, and

[6] At the time of publication, the Planning and Development Act 2000 is under review. The provisions of any new Act and Regulations will supersede the advice contained in these guidelines and readers should check the website of the Houses of the Oireachtas for the most up-to-date information

[7] See Planning and Development Act 2000 (as amended), Section 4(1)(h)

[8] See Planning and Development Act 2000 (as amended) Section 5

[9] Government of Ireland (2011)

d) all fixtures and features which form part of the interior or exterior of the above structures.

Planning permission is required for all works that would materially affect the character of a protected structure, a proposed protected structure or any element of the structure that contributes to its special interest.[10] The owner or occupier of a protected structure may make a written request to the relevant planning authority under Section 57(2) of the Act to issue a declaration as to the type of works it considers would or would not materially affect the character of the particular protected structure.

1.3.1.3 Architectural Conservation Areas

Under the Planning and Development Act 2000 (as amended), an ACA is a place, area, group of structures or townscape that:

- is of special architectural, historical, archaeological, artistic, cultural, scientific, social or technical interest, or
- contributes to the appreciation of a protected structure.

The local authority development plan may be consulted to establish if a building is located within an ACA. In addition, the local authority may have published a written statement on its detailed policies for the ACA.

Carrying out works to the exterior of a structure located in an ACA, which would materially affect the character of the area, requires planning permission. Such works may include, but are not limited to:

- changing the type of slate or roofing material
- changing the height or configuration of a roof
- changing the design, dimensions, position or material of a chimney
- removing render from an external wall
- rendering, plastering or painting a previously bare wall
- changing the type, design or material of windows
- changing the design or materials of window sills
- changing the design or material of external doors
- changing the design or materials of a shopfront
- adding, removing, or altering architectural details, elements or finishes such as quoins, mouldings, fascias, bargeboards, ridge-tiles, chimney caps or pots, plaques, jostle stones, paving or kerbing, railings or gates
- adding solar panels or other renewable energy systems to buildings or erecting free-standing installations within the ACA.

Where there is doubt as to whether external works would affect the character of an ACA, advice should be sought from the architectural conservation officer in the local authority.

1.3.2 National Monuments Acts[11]

Structures and sites may be protected under the National Monument Acts 1930 to 2014. When dealing with older buildings, it is important to establish their legal status by checking if they are included in the Record of Monuments and Places (RMP).[12] The RMP is a map dataset for each county that is maintained by the National Monuments Service of the Department of Housing, Local Government and Heritage and can be viewed on the website www.archaeology.ie or in a county library or main local authority office.

[10] See Planning and Development Act 2000 (as amended) Section 57(1)

[11] In October 2023, the Historic and Archaeological Heritage and Miscellaneous Provisions Act 2023 was enacted to replace the National Monuments Acts 1930 to 2014. When commenced, the provisions of the new Act and Regulations will supersede the advice contained in these guidelines and readers should check the website of the Houses of the Oireachtas for the most up-to-date information

[12] National Monuments Service, Record of Monuments and Places. Available at: https://www.archaeology.ie/publications-forms-legislation/record-of-monuments-and-places

Buildings subject to the National Monuments Acts are exempt from the requirements of the Building Regulations under Class 8, third schedule of the Building Regulations 1997 (SI 497 of 1997).

To comply with the legislation, a person intending to carry out works to a privately owned building, structure or site that is included within the RMP must give two months' notice to the Minister for Housing, Local Government and Heritage before commencing works. Where a structure is a national monument in the ownership or guardianship of the Minister for Housing, Local Government and Heritage or a local authority, or is a national monument subject to a Preservation Order, Ministerial Consent to carry out works must be obtained before any works commence.

In responding to the required notice or application for Ministerial Consent, the National Monuments Service may make recommendations in the interest of the protection of the archaeological remains, may request further information or pre-works recording, and may grant or refuse permission to carry out the works. Where archaeological monitoring or excavation is a condition of the Ministerial Consent, a licensed eligible archaeologist must be engaged.

Anyone dealing with a traditional building or structure that is subject to the National Monuments Acts should engage with the National Monuments Service and the local authority architectural conservation officer, heritage officer and/or archaeologist for advice and guidance. They may also wish to consult a number of helpful publications such as *Framework and Principles for the Protection of the Archaeological Heritage*[13] and *Archaeology in the Planning Process*.[14]

1.3.3 Building Control[15]

To ensure the safety of people in and around buildings, the design and construction of buildings is regulated under the Building Control Act 1990 (as amended). The Building Control Act sets out the primary purpose for which the Building Regulations may be made.

1.3.3.1 Building Regulations

The Building Regulations 1997 (as amended) apply to the design and construction of buildings. The minimum performance requirements that a building must achieve are set out in the Second Schedule to the Building Regulations. In general, building regulations apply to the construction of new buildings, to major renovation and to extensions and material alterations to existing buildings. In addition, certain parts of the regulations apply to an existing building where a material change of use takes place.

Guidance on compliance with the various parts of the Building Regulations is given in the associated Technical Guidance Documents (TGDs). Where works are carried out in accordance with the TGDs, this will, prima facie, indicate compliance with the Building Regulations. However, the adoption of an approach other than that outlined in the guidance is not precluded, provided that the relevant requirements of the regulations are complied with.

[13] Government of Ireland (1999)

[14] Government of Ireland (2021b)

[15] Nothing in this guidance document takes precedence over the provisions of the Building Control Acts, the Building Control Regulations, the Building Regulations and the associated Technical Guidance Documents.

Paragraph 0.6 of TGD L 'Application to buildings of architectural or historic interest'

Part L and the European Union (Energy Performance of Buildings) Regulations 2019 do not apply to works (including extensions) to an existing building which is a 'protected structure' or a 'proposed protected structure' within the meaning of the Planning and Development Act 2000 (No.30 of 2000). Nevertheless, the application of this Part and of the European Union (Energy Performance of Buildings) Regulations 2019 may pose particular difficulties for habitable buildings which, although not protected structures or proposed protected structures, may be of architectural or historical interest including buildings of traditional construction with permeable fabric that both absorbs and readily allows the evaporation of moisture.

The aim should be to improve the energy efficiency as far as is reasonably practicable. The work should not prejudice the character of the building or increase the risk of long-term deterioration of the building fabric.

I.S.EN 16883:2017 Conservation of cultural heritage —Guidelines for improving the energy performance of historic buildings provides guidance for sustainably improving the energy performance of historic buildings, e.g. historically, architecturally or culturally valuable buildings, while respecting their heritage significance.

Works such as the replacement of doors, windows and rooflights, the provision of internal and/or external insulation and damp-proofing to walls and basements, insulation to the underside of slating and provision of roof vents and ducting of pipework could all affect the character of the structure.

In general, the type of works described above should be carefully assessed for their material and visual impact on the structure.

Historic windows and doors should where possible be repaired rather than replaced, and internal insulation and damp-proofing should not disrupt or damage historic plasterwork or flagstones and should not introduce further moisture into the structure.

Roof insulation should be achieved without damage to slating (either during the works or from erosion due to condensation) and obtrusive vents should not affect the character of the roof.

In specific cases including replacement of historic windows and insulation of vapour permeable constructions, relaxation of the values proposed may be acceptable to the local building control authority, if it can be shown to be necessary in order to preserve the architectural and historic integrity of the particular building.

In specific cases, services and their controls can play a large part in improving energy efficiency. In most traditional buildings, building services such as heating systems, plumbing and electrical installations are not original to the building and there may therefore be some flexibility in altering them.

Detailed information relating to the application of building regulations to certain buildings is contained in the publication *Bringing Back Homes – Manual for the reuse of existing buildings*[16] with respect to:

- material alterations, extensions and repair or renewals
- provision of services, fittings, and equipment (by way of new work or by way of replacement), and
- material changes of use of existing buildings.

The following section provides guidance, additional to that contained in *Bringing Back Homes*, with respect to 'major renovation' in traditionally built buildings.

The Building Regulations provide that when a building undergoes 'major renovation', the minimum energy performance requirement of the building or the renovated part thereof is upgraded to meet the cost-optimal level of energy performance in so far as this is technically, functionally and economically feasible. 'Major renovation' means the renovation of a building where more than 25% of the surface of the building envelope undergoes renovation. The surface area of the building's thermal envelope means the entire surface area of a building through which it can lose heat to the external environment or the ground, including all heat loss areas of walls, windows, external envelope floors and roof.

The elemental works that are included in the surface area calculation for major renovation are summarised in Table 1. According to TGD L, where major renovations to walls, roofs and ground floors constitute essential repairs, e.g. repair or renewal of works due to fire, storm, flood or damage as a result of a material defect, it is not considered economically feasible to bring these renovations to a cost-optimal level. Additionally, painting, replastering, rendering, re-slating, retiling and insulation of ceilings are not considered major renovation works.

Table 1: Elemental works that are included in the 25% surface area calculation for major renovation

External walls renovation	External insulation of the heat-loss walls Replacement or upgrade of the external walls' structure Internal lining of the surface of the heat-loss walls
Windows renovation	Replacement of windows
Roof renovation	Replacement of roof structure
Floors renovation	Replacement of floors
Extension	Extension works which affect more than 25% of the surface area of the existing dwelling

For dwellings, the cost-optimal level is achieved by:

- reaching an energy performance target of no more than 125 kWh/m²/yr when calculated in DEAP, or
- implementing the energy performance improvements as set out in Column 3, Table 7 of TGD L – Dwellings, as far as they are technically, functionally and economically feasible.

[16] Government of Ireland (2018)

Table 2: Cost-optimal works activated by major renovation (taken from Table 7, TGD L 2021). This table, and the references within it, should be read in conjunction with Technical Guidance Document L – Conservation of Fuel and Energy – Dwellings

<table>
<tr><th>Major renovation > 25% surface area[1,2,3,5]</th><th>Cost-optimal level as calculated in DEAP (paragraph 2.3.3 a.)</th><th>Works to bring dwelling to cost-optimal level in so far as they are technically, economically and functionally feasible (paragraph 2.3.3 b.)</th></tr>
<tr><td>External walls renovation</td><td rowspan="4">The cost-optimal performance level to be achieved is 125 kWh/m^2/yr</td><td rowspan="4">Upgrade insulation at ceiling level (roof) where U-values are greater than in Table 5
and
Oil or gas boiler replacement[6] and controls upgrade where the oil or gas boiler is more than 15 years old and efficiency less than 86%
and/or
Replacement of electric storage heating[7] systems where more than 15 years old and with heat retention not less than 45% measured according to IS EN 60531</td></tr>
<tr><td>External walls and windows renovation</td></tr>
<tr><td>External walls and roof renovation</td></tr>
<tr><td>External walls and floor renovation</td></tr>
<tr><td>New extension affecting more than 25% of the surface area of the existing dwelling's envelope (see 2.3.6)</td><td>The cost-optimal performance level to be achieved is 125 kWh/m^2/yr</td><td>Upgrade insulation at ceiling level (roof) where U-values are greater than in Table 5
and
Oil or gas boiler replacement[6] and controls upgrade where the oil or gas boiler is more than 15 years old and efficiency less than 86%
and/or
Replacement of electric storage heating[7] systems where more than 15 years old and with heat retention not less than 45% measured according to IS EN 60531
and
Upgrade insulation at wall level where U-values are greater than in Table 5</td></tr>
<tr><td>Windows renovation</td><td rowspan="6">Not applicable[4]</td><td rowspan="6">Not applicable[4]</td></tr>
<tr><td>Roof renovation</td></tr>
<tr><td>Floor renovation</td></tr>
<tr><td>Roof and windows renovation</td></tr>
<tr><td>Windows and floor renovation</td></tr>
<tr><td>Roof and floor renovation</td></tr>
</table>

Notes:
1. Where works are planned as a single project.
2. Where major renovations to walls, roofs and ground floors constitute essential repairs, e.g. repair or renewal of works due to fire, storm or flood damage or as a result of a material defect, e.g. reactive pyrite in sub-floor hardcore, it is not considered economically feasible to bring these renovations to a cost-optimal level.
3. Major renovation of external wall elements should also meet the requirements of Table 5.
4. It is not considered technically, functionally or economically feasible to bring the whole building to cost-optimal level when replacing the surface area of these elements.
5. Subject to the requirements of Table 5 for material alterations and window and door replacement.
6. Oil or gas boiler replacement should be with a boiler or a renewable energy source with an efficiency as given in Section 2.2.2.
7. Replacement of electric storage heating should be with a heat generator with an efficiency as given in Section 2.2.2.

For buildings other than dwellings, upgrading the heating, controls, ventilation and lighting systems to modern standards of energy efficiency is generally considered cost-optimal. This may allow for the emphasis to be placed on building systems rather than extensive fabric interventions. Alternatively, minimum whole-building energy performance targets for different buildings by use have been calculated as cost-optimal.

The guidance in this document may be used to inform approaches to the meet provisions of Technical Guidance Documents where referred to by those guidance documents when improving the energy efficiency of traditional buildings:

- TGD C – Site Preparation and Moisture Resistance
- TGD D – Materials & Workmanship
- TGD F – Ventilation
- TGD J – Heat Producing Appliances
- TGD L – Conservation of Fuel & Energy – Dwellings
- TGD L – Conservation of Fuel & Energy – Buildings other than dwellings.

It is also important to consider:

- TGD A – Structures
- TGD B – Fire Safety
- TGD E – Sound
- TGD G – Hygiene
- TGD K – Stairways, Ladders, Ramps and Guards
- TGD H – Drainage and Waste Water Disposal
- TGD M – Access and Use.

For existing buildings, the applicable requirements of TGD L are covered by Section 2 of that document, which includes specific provisions that apply to the replacement of external doors, windows and rooflights and to the replacement of oil or gas boilers.

1.3.3.2 Building Control Regulations

The Building Control Regulations 1997 (as amended) provide for matters of procedure, administration and control for the purposes of securing the implementation of, and compliance with, the requirements of Building Regulations.

1.3.4 Energy Performance of Buildings Directive

The Energy Performance of Building Directive (EPBD)[17] sets requirements at an EU level for Member States to improve the energy performance of buildings and make an important contribution to the reduction of greenhouse-gas emissions, including installation of appropriate infrastructure to enable the installation of recharging points for electric vehicles.

1.3.4.1 Building Energy Rating (BER) and Traditional Buildings

The EPBD promotes energy efficiency in all buildings across the EU. One of its requirements is that all new, and certain existing, buildings within the EU have an energy performance certificate. The implementation of performance certificates in Ireland is managed by the Sustainable Energy Authority of Ireland (SEAI) and takes the form of BER for all building types, calculated by the Dwelling Energy Assessment Procedure (DEAP) for dwellings and by the Non-Dwelling Energy Assessment Procedure (NEAP) for other building types. Public buildings greater than 250m^2 and large buildings (greater than 500m^2) that are frequently visited by the public are also required to have Display Energy Certificates. The DEAP and NEAP methodologies and software calculate primary energy use, the associated CO_2 emissions and the renewable energy provided for space heating and (where applicable) cooling, ventilation, water heating and lighting under standardised conditions of use. They are also the compliance tool specified in TGD L. The software and manual are freely available online.[18]

[17] At the time of publication, the EPBD is under review. Readers should check the Official Journal of the European Union for the most up-to-date information: https://eur-lex.europa.eu/

[18] DEAP software: https://www.seai.ie/home-energy/building-energy-rating-ber/support-for-ber-assessors/domestic-ber-resources/deap4-software/ - NEAP software: https://www.seai.ie/grants/supports-for-contractors/neap/sbemie-software/

BER certificates are required for all new buildings and existing buildings undergoing transaction, whether lease or sale. While buildings subject to the National Monuments Acts, protected structures, proposed protected structures, places of worship and other specified building types are exempt, all other traditional buildings are required to have a BER certificate when let or sold. The BER assesses the energy performance of the building, allowing potential buyers and tenants to take energy performance into consideration in their decision to purchase or rent a property. The BER rating may also be a consideration for financial institutions in mortgage lending.

Following assessment of the building by a BER assessor, a certificate is prepared and issued to the building owner along with a BER Advisory Report. The energy rating displays both the energy requirement of the building in terms of 'primary energy' and the resultant CO_2 emissions. Normally a building owner thinks in terms of 'delivered energy', also known as 'final energy'. Delivered energy corresponds to the energy consumption that would normally appear on the energy bills of the building. Primary energy includes delivered energy, plus an allowance for the energy 'overhead' incurred in extracting, processing or generating, and transporting a fuel or other energy carrier to the building.

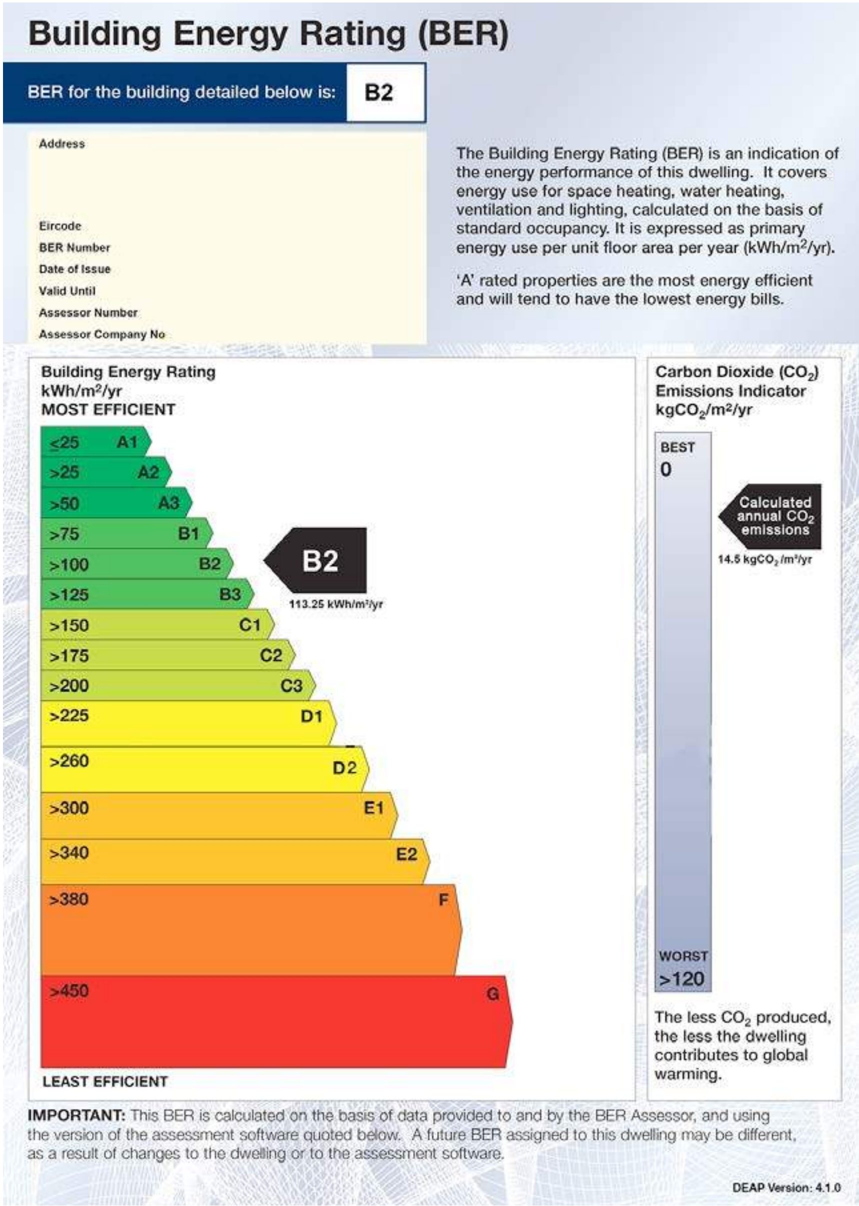


Figure 4: Sample BER certificate for dwellings. The most energy-efficient rating is currently A1 (green); the least efficient G (red)

In the assessment methodology, the size and form of a building are taken into account and its floor area is used to determine the number of assumed occupants. In the case of a dwelling, the rating is based on a standardised heating schedule enabling prospective occupiers to compare the energy efficiency of, in practice, what are often very differing buildings. The BER is not necessarily always a good predictor of energy bills (unless the building is largely similar to the reference values, which are for a three-bed semi-detached house with all rooms heated to 18°C and where the main living room is heated to 21°C for 56 hours per week).[19] A building's BER does not take account of its location within the country (whether in the colder north or warmer south) but does consider orientation relative to the sun. It is also important to bear in mind that it does not take account of actual energy usage but assumes a standardised usage pattern.

The rate at which heat is transferred through the external envelope of a building is expressed as a U-value. At present, the standard calculation for older buildings often relies on default values for heat loss calculations. These default U-values are conservative and, at times, may poorly represent an older building's ability to retain heat. If the BER assessor knows the build-up of the wall, they are able to calculate the U-value based on the materials and properties of construction. This is a preferable method to use where the calculations can be based on certified data. However, these can be difficult to determine in traditional buildings without boring a core through the external walls, which may not be possible nor appropriate. Calculated U-values, where supported by known material properties and sufficient evidence of wall make-up, can be used in BER calculations[20] and this is often a preferable method to use for traditional construction (see Section 2.2.7 for further details). Research is currently underway to determine the material properties for many traditional wall materials used in Ireland.

On completion of a BER calculation for an existing building, the assessment software generates a list of recommendations for upgrading the building in the form of an Advisory Report. It should be noted that these recommendations have in general been designed for existing buildings of modern construction rather than traditional buildings. As the BER assessor is responsible for advising which recommendations are appropriate for any particular property, it is important to ensure that the assessor understands how traditional buildings perform. Inappropriate recommendations, if implemented, could cause long-term damage to building fabric. If such a risk has been identified, a suitably qualified expert (see Table 3) should be consulted prior to undertaking works recommended in a BER advisory report.

1.4 Recommended Skills and Experience

The energy-efficiency upgrading of traditional buildings should generally be undertaken by competent specifiers and installers with the right skills and experience, in line with this guidance. This is necessary to avoid any adverse consequences, or damage to the building fabric or the wellbeing of its occupants. Consultants should understand traditional construction and its specific renovation requirements, be competent in building conservation and hold relevant professional training and accreditation.

[19] See Section 7.1, Heating Schedule, https://www.seai.ie/publications/DEAP_Manual.pdf

[20] See DEAP Manual, Section 3.1, U-values of Opaque Elements, https://www.seai.ie/publications/DEAP_Manual.pdf

Table 3: Recommended qualifications for building professionals, specifiers and installers.
Note: Not all professionals will be required on all projects

Building works specifier	Recommended qualification	Additional qualifications/competencies
Architect	RIAI-registered architect	RIAI Accredited Conservation Architect,[21] experience in the cost-optimal thermal upgrade of traditional buildings
Building surveyor	SCSI-registered building surveyor	Conservation accreditation[21a] + an understanding of applied building physics relevant to traditional buildings Experience in the thermal upgrade of traditional buildings
Structural engineer	Engineers Ireland-registered structural engineer	Chartered engineer; Conservation Accreditation Register for Engineers[22] Experience in the cost-optimal thermal upgrade of traditional buildings
Conservation consultant	Level 8 NFQ professional degree in conservation with relevant experience Understanding of applied building physics relevant to traditional buildings	Experience in the cost-optimal thermal upgrade of traditional buildings
Architectural technologist	Level 8 NFQ degree in architectural technology Understanding of applied building physics relevant to traditional buildings	RIAI architectural technologist membership[23] Experience in the cost-optimal thermal upgrade of traditional buildings
Mechanical & electrical engineer	Chartered Building Services Engineer with the Chartered Institution of Building Services Engineers or Engineers Ireland	Experience in working on traditional buildings; Knowledge of renewable energy technologies
Energy auditor/BER assessor	Domestic assessors: Level 6 NFQ Advanced/ Higher Certificate in construction studies Non-domestic assessors: Level 7 NFQ Degree in construction studies + professional body membership at the specified grade[24]	On the SEAI Register + an understanding of applied building physics relevant to traditional buildings
Thermal bridge modeller	On National Standards Authority of Ireland (NSAI) Register of Thermal Modellers[25]	Understanding of applied building physics relevant to traditional buildings
Hygrothermal modeller	No register currently available	Relevant experience of traditional construction and/or training + appropriate professional indemnity cover
Ventilation validator	On NSAI Register of Ventilation Validators[26]	
Air permeability tester	On NSAI Register of Airtightness Testers[27]	
Archaeologist	Level 8 NFQ professional degree in archaeology and relevant experience	A licensed eligible archaeologist[28]
Installer	Relevant to discipline	Experience working on traditional buildings

[21] See https://www.riai.ie/work-with-an-architect/conservation-skills
[21a] See https://scsi.ie/building-conservation-accreditation/
[22] See https://www.engineersireland.ie/Professionals/Communities-Groups/Engineering-Divisions/Structures-and-construction/Conservation-Accreditation-Register-for-Engineers
[23] See https://www.riai.ie/join-the-riai/architectural-technologist-membership
[24] See https://www.seai.ie/register-with-seai/ber-assessor/pre-qualification-criteri/
[25] See https://www.nsai.ie/certification/agrement-certification/thermal-modellers-scheme/
[26] See https://www.nsai.ie/certification/agrement-certification/ventilation-validation-registration-scheme/
[27] See https://www.nsai.ie/certification/agrement-certification/air-tightness-testing/
[28] See https://www.archaeology.ie/licences

Table 4: The range of skills provided by different building professionals and an indication of their involvement on a retrofitting project of a typical, mixed-use, traditionally constructed, urban building. Note: this is an indicative list only of the building professionals that may be needed, depending on the nature of the project. Not all projects will require a full team of professionals

Core activity (large dot) · Support activity (small dot)

Services	Architect	Architect (Conservation Accredited)	Building Surveyor	Building Surveyor (Conservation Accredited)	Conservation Consultant	Structural Engineer	Architectural Technologist	Archaeologist	Mechanical & Electrical Engineer	Energy Auditor	BER Assessor	Thermal Bridge Modeller	Hygrothermal Modeller	Ventilation Validator	Air Permeability Tester
Design of fabric efficiency upgrades	Core	Core	Core	Core	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
Design of building conservation measures	Support	Core	Support	Core	Core	Support	Support	Support							
Design of structural repairs or alterations	Support	Support	Support	Support	Support	Core	Support	Support							
Design of works	Core	Core	Core	Core	Support	Core	Support	Support	Support						
Building condition survey	Support	Support	Core	Core	Core	Core	Support	Support							
Heritage impact assessment	Support	Core	Support	Core	Core	Support	Support	Support							
Survey and monitoring of alterations to any historical/archaeological features in a building	Support	Core	Support	Core	Core	Support	Support	Core							
Project management and monitoring	Core	Core	Core	Core	Support	Core									
Ensuring compliance with building regulations	Core	Core	Core	Core	Support	Core	Support		Support	Support	Support	Support	Support	Support	Support

Table 4 *continued*

Core activity = large circle; Support activity = small circle

Services	Architect	Architect (Conservation Accredited)	Building Surveyor	Building Surveyor (Conservation Accredited)	Conservation Consultant	Structural Engineer	Architectural Technologist	Archaeologist	Mechanical & Electrical Engineer	Energy Auditor	BER Assessor	Thermal Bridge Modeller	Hygrothermal Modeller	Ventilation Validator	Air Permeability Tester
Design of M&E services	Support	Support	Support	Support					Core	Support				Support	Support
Energy audit	Core	Core	Core	Core	Support		Support		Support	Core	Support		Support		
BER assessment	Core	Core	Core	Core	Support	Core	Support			Support	Core	Support	Support		
Thermal bridge calculation	Support	Support	Support	Support	Support		Support				Support	Core	Core		
Condensation risk assessment	Support	Support	Support	Support	Support		Support				Support	Support	Core		
U-value calculation or in situ measurements	Support	Support	Support	Support	Support		Support				Support	Support	Core		
Indoor air quality monitoring	Support	Support	Support	Support					Support		Support			Core	Core
Testing and certification of airtightness	Support	Support	Support	Support							Support			Core	Core
Specification of ventilation requirements	Support	Support	Support	Support					Core		Support		Support	Support	Support

A building professional accredited in building conservation will have competence working on traditional construction and be able to advise on, and specify, suitable measures for traditional building energy upgrades. If the building professional leading the project lacks sufficient conservation experience, additional advice from a conservation consultant may be required.

Tables 3 and 4 outline the different professionals/consultants who *may* be required for energy-upgrading projects and the services they provide. These are non-exhaustive, indicative lists based on large-scale complex retrofit projects. Fewer professionals and services may be required for small-scale and domestic retrofit projects. Certain low-risk interventions may be undertaken by skilled and experienced installers or contractors with a knowledge of traditional construction. As a general rule, a competent building professional with expertise in building conservation will be required when considering works on a protected structure.

1.5 Considering the Full Environmental Impact of Construction

Under the Climate Action and Low Carbon Development (Amendment) Act 2021, Ireland's national climate objective requires the state to pursue and achieve, by no later than the end of the year 2050, the transition to a climate-resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy. The Act also provides for a reduction of 51% in GHG emissions by 2030, compared to 2018 levels.[29]

The environmental benefit of upgrading the energy efficiency of existing buildings lies in the fact that they will require less energy for heating and cooling, which enables their owners or occupants to reduce energy waste and emissions while also saving on their energy bills. A further benefit is that fewer material resources would generally be required to upgrade to an energy-

Embodied carbon: carbon-dioxide equivalent (CO_2eq) emissions resulting from the production, transportation and installation of building materials and components on site. Embodied emissions also include emissions from maintenance, repairs, replacement and ultimately the demolition and disposal of building materials over the lifetime of the building. Embodied carbon emissions can account for a large percentage of a building's total life cycle emissions. Retention of buildings saves the embodied carbon of construction of new buildings, which contain many high embodied carbon materials such as cement mortars, steel, aluminium, PVC products and petroleum-based insulations. Traditional materials such as lime mortars and renders, timber or native thatch will tend to have lower associated embodied carbon emissions.

Operational carbon: CO_2eq emissions that result from the day-to-day use of a building through energy consumption. The operational emissions of a building can account for a large portion of the building's life cycle emissions (the accumulation of emissions throughout the entire operation of the building).

[29] Government of Ireland (2023a)

efficient building than for the construction of replacement buildings. The large-scale, cost-optimal retrofit of the existing building stock will therefore contribute to total CO_2 emission reductions and energy saving from the built environment in a relatively short period.

The Climate Action Plan recognises that a range of additional measures will be required to meet the CO_2 emission reduction targets for the built environment, including fabric and energy-efficiency improvements for existing buildings and the promotion of lower carbon materials. This aligns with the EU Renovation Wave initiative, which aims to expand the market for sustainable construction products and services.[30]

To demonstrate the importance of considering the embodied emissions of materials, two notable studies have used life cycle assessment (LCA) to compare the embodied and operational emissions of three scenarios:

- continuing to operate the case study building as-is
- retrofitting it for improved energy efficiency
- demolishing the building and replacing it with a new building constructed to meet current building regulations and energy-efficiency standards.

The first study was based in the United States and found that it can take between 10 and 80 years for a new, energy-efficient building to overcome, through more efficient operations, the negative climate-change impacts that are created during the construction process.[31] The second, more recent, study focused on typical traditional buildings in the UK[32] and found that this emission recovery period could extend up to 120 years.

Research is currently underway to explore potential methodologies for the calculation of whole-life carbon assessment of traditional building retrofit in the Irish context.

To make a truly sustainable decision when planning alterations, the whole life of the building materials may be taken into account through whole-life carbon assessments. A whole-life carbon approach allows a building owner to identify the 'best combined opportunities for reducing lifetime emissions, and also helps to avoid any unintended consequences of focusing on operational emissions alone.'[33] The whole-life carbon approach uses LCA to calculate the total carbon footprint of a building project by following the methodology outlined in I.S. EN 15978:2011. LCA can generally be done in tandem with Life Cycle Costing (LCC) which considers all monetary costs associated with the life cycle of the building (e.g., design, construction, operation, maintenance, and demolition/recycling).

The lifespan of materials, components and construction products is an important consideration when carrying out an LCA. A material or product that can be easily repaired, and for which the skills for those repairs exist, is more likely to have a longer lifespan than materials or products that are more likely to be replaced. This assessment is useful when comparing the environmental impact of different materials or products.

It is also important to note that some materials or systems may have an initially high embodied carbon but provide high efficiencies and operational savings, thereby reducing the building's overall life cycle emissions within

[30] European Commission (2020)

[31] Frey et al. (2011)

[32] Duffy et al (2020a)

[33] Sturgis and Papakosta (2017)

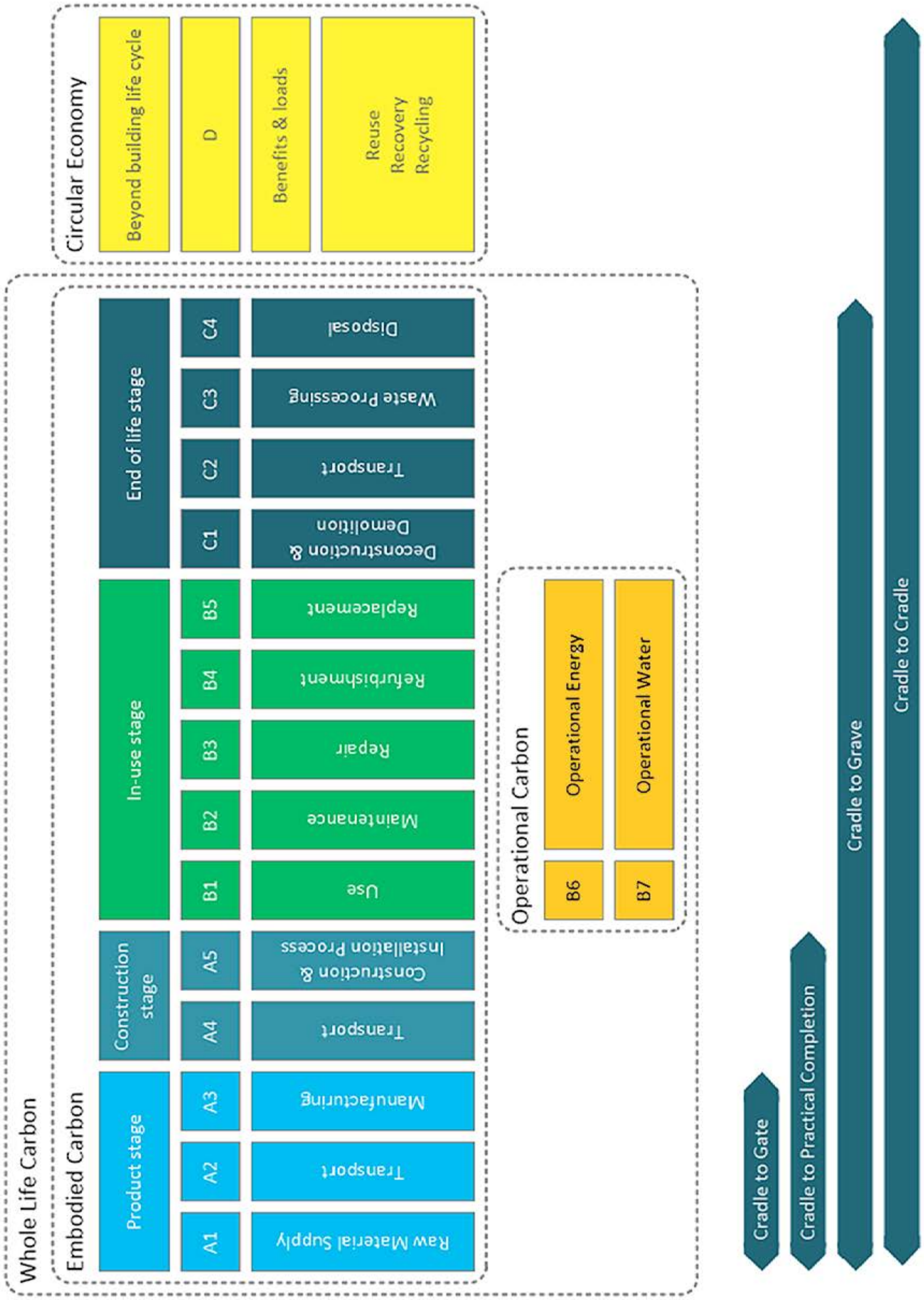


Figure 5: The life cycle stages (referred to as life cycle modules) reported in EPDs which assess the Global Warming Potential associated with construction[34]

[34] I.S. EN 15978:2011

its lifespan. Therefore, considering embodied emissions and operational emissions in tandem (known as ‘whole-life carbon’) is a more complete way of calculating the carbon footprint of a building project.

Resources are available to homeowners and building professionals to help them choose low-carbon products. Voluntary Environmental Product Declarations (EPDs) or anticipated mandatory CE marking for conformance with environmental product standards are used to communicate the overall environmental impact of the production of a material and the possible impacts of its use and disposal.

Global warming potential (GWP) is a measure of how much heat a GHG traps in the atmosphere (called ‘radiative forcing’) over certain time periods. The government has agreed to use this measure to add up the impact of emissions of different gases and how they contribute to global warming. In an LCA assessment, whole-life carbon is measured as GWP and expressed in $kgCO_2eq$ (kilograms of CO_2 equivalents). GWP is also proposed to be added to energy performance certificates under the new EPBD.

1.6 Building Renovation Passports

For various reasons (e.g. financial or practical), the cost-optimal renovation of an existing building may not always be achievable in one go. However, where such renovation is taken in stages, it needs to be carefully planned in order to ensure that one renovation step does not preclude subsequent steps. This ‘lock-in effect’ may happen when works are implemented that make it harder or costlier to implement future planned renovation measures.

To assist this process, Building Renovation Passports (BRPs) can be developed to facilitate a smart, well-planned, staged energy upgrading of a building. BRPs can empower building owners to undertake cost-optimal energy upgrading works by providing a set of actions, a sequenced plan and estimated costs, which will help to address the barriers to consumer decision-making by giving building owners the technical information they need to make informed choices. They will also help embed long-term climate goals into the short- and medium-term renovation steps.

Although BRPs are not yet widely available in Ireland, they may be introduced in the coming years and the principles of the passport may be helpful where single-stage retrofit is not possible in order to avoid lock-in decisions, which might compromise final energy-efficiency targets.

Chapter 2

Understanding Traditional Buildings

This chapter discusses:

- the physics of traditional buildings, how heat and moisture move through a building and how this can be dealt with, taking into consideration the importance of ventilation and indoor air quality
- the various methods for assessment of a building to determine any thermal bridges, air leakage and existing damage
- the calculation method for U-values relevant to traditional buildings
- potential health risks associated with the build-up of harmful substances/gases in a building and how to avoid them

To ensure that the works undertaken do not damage the special qualities of a traditional building, it is important to understand some of the basic principles of good building conservation. Understanding the building is also paramount prior to considering any form of energy upgrading works. It is important to know the approximate construction date of the building, the materials of which it is constructed, and the construction methods used. These basic factors will dictate what can, cannot or should not be done to the building. A fourth factor to consider is the existence of later interventions: for example, have there been inappropriate interventions such as the application of a cement-based render or repointing of brickwork with a cement-based mortar? Has the interior been dry lined inappropriately? Such inappropriate interventions can be detrimental to traditional building fabric, and many require reversal before additional works can be successful.

2.1 Traditional Building Physics

2.1.1 Thermal Mass and Heat Storage/Loss

Different materials absorb and release heat at different rates. Thermal mass is the ability of high-density materials such as brick and stone to absorb heat, retain it and then release it slowly over time (termed 'thermal inertia'), helping to moderate the temperature fluctuations within a room ('decrement delay'). A thermally lightweight structure responds very quickly to solar gain or heating but is less effective in storing energy for use later, which can result in larger temperature swings within a room.

It should be noted that a heavy masonry wall and a well-insulated lightweight structure with the same U-value (rate of heat loss) have very different responses to internal space heating. Traditional buildings with a high thermal mass have a relatively slow response time. External insulation preserves and enhances thermal-mass effects; internal insulation devalues them. The effects of thermal mass on energy use are included in the NEAP/DEAP calculation.

Heat loss from the interior of a building happens in two principal ways – by transfer (conduction) through the materials that make up the external envelope of the building (measured as a U-value) or by the exchange of air between the interior and the exterior environment; that is, ventilation and/or air leakage/infiltration. In traditional buildings, the highest percentage of heat is typically lost through the walls (35%), followed by the roofs (25%), floors (15%), windows (10–15%) and draughts (10%).

Each building element has its own rate of heat transfer, described by its U-value. The U-value (see Section 2.2.7 for further details) is a measure of the rate of heat transfer through a building element. The more slowly the heat travels through a material, the better an insulator it is and the lower its U-value. For any given construction, independent of U-value, heat loss is also directly

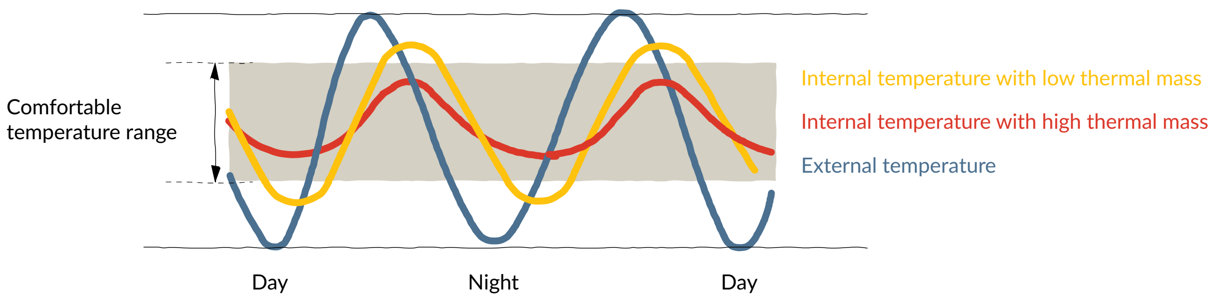


Figure 6: A graph showing the summertime temperature changes within buildings with high thermal mass (red line) and with low thermal mass (yellow line). As can be seen by the red line, less extreme changes of temperature are experienced inside the building with the higher thermal mass, all else being equal (Image from *Advice Series: Energy Efficiency in Traditional Buildings*, 2010)

related to the temperature difference between the exterior and interior environments.

Increased moisture in the fabric of a building reduces its ability to insulate and leads to a higher rate of heat loss. As a result, the effective heat loss through the wall can increase by up to 30%. Common causes of moisture ingress include damp penetration in walls due to leaking gutters, cracked sills, defective render or through the removal of render, poorly fitting windows and frames, and defective chimneys. The inappropriate use of cement renders on a traditional building constructed using lime mortars can trap moisture within the wall. Plant growth in walls and chimneys is also a common sign of poor maintenance and is a result of moisture ingress. It is therefore important to ensure that buildings are in a good state of maintenance and that sources of water ingress and/or damp are rectified before energy-upgrading measures are considered to improve U-values.

The guidance in this document is predicated on the notion that the receiving building is well maintained and free from such defects.

2.1.2 Moisture Movement

Moisture movement through the building fabric occurs via a number of mechanisms – rainfall, convection and diffusion – each with its own defences. Rain is kept out by an effective roof with well-functioning rainwater goods, drips and renders; diffusion is minimised by good airtightness and is facilitated by vapour-permeable fabric.

Wetting due to driving rain remains the largest single source of moisture for traditional buildings. However, air movement through the building envelope ('convection') can also result in significant amounts of moisture being deposited within the building fabric. This underlines the importance of fabric airtightness, especially at vulnerable junctions where structural connections of timber elements may be present, e.g. wall plates or joist ends. Other common mechanisms for moisture transport are vapour diffusion and capillary action.

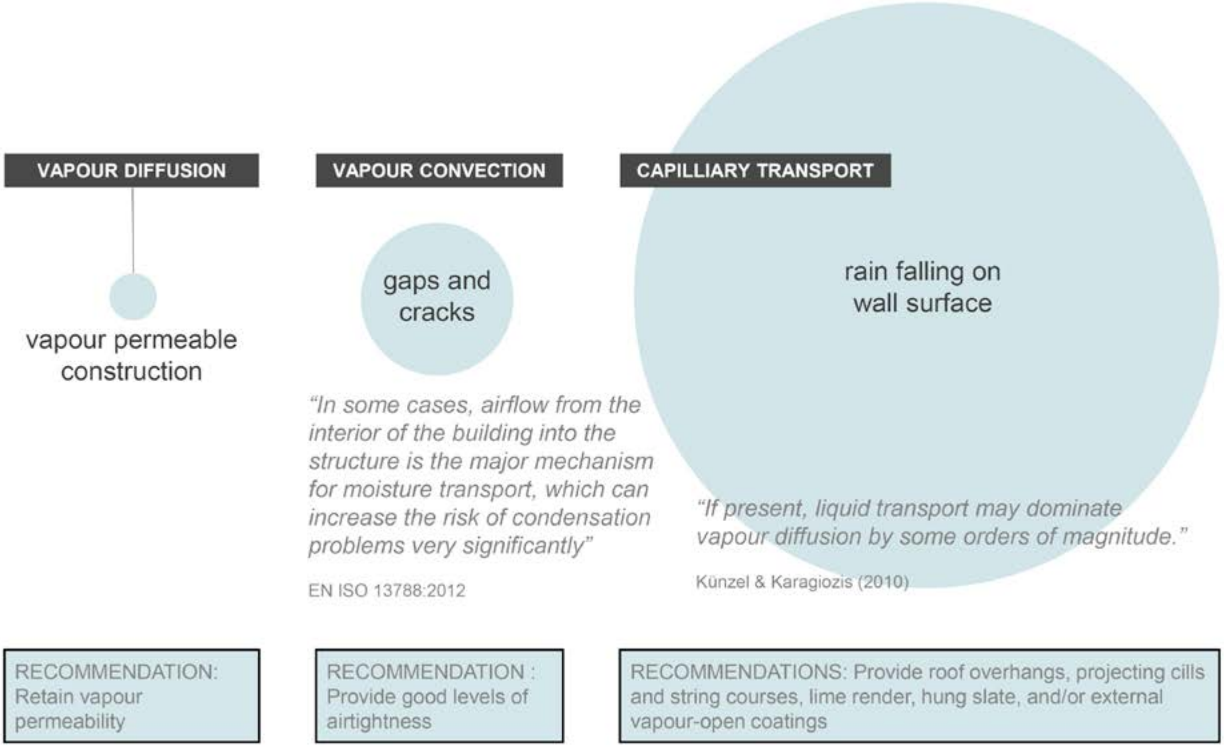


Figure 7: Relative wetting mechanisms for solid walls (Courtesy of Beñat Arregi, TU Dublin)

Diffusion occurs when moisture in the form of vapour is transferred through construction materials from an area of high vapour pressure (usually indoor heated air) to an area of low vapour pressure (usually outdoor air) via a naturally existing vapour differential.

Capillary action is the movement of water and vapour molecules through the porous structure of materials. The size and shape of pores has a significant impact on the movement of vapour through materials. Some traditional construction types make use of capillary breaks to control the passage of moisture through the building envelope, e.g. slate-hanging on the outside of buildings with solid walls.

In general, traditional buildings often have relatively absorptive external faces, e.g. brick, where it is common for driving rain to penetrate the outer layers of the wall and move into the building fabric, sometimes aided by solar gain on this same façade providing the thermal energy to reverse the normal vapour pressure differential, pushing 'solar-driven' moisture vapour towards the inner face of the wall. This is why it is important to maintain the vapour permeability of the construction towards both inside and outside, while ensuring good airtightness. Lime renders and plasters were traditionally used as a moisture buffer, limiting the amount of rainwater and atmospheric moisture absorbed while allowing moisture within the solid masonry to pass through the wall to evaporate both internally in winter and externally during drier conditions. Restricting the ability of the wall to dry to either side can lead to a build-up of moisture within the fabric of the wall itself.

Moisture can also enter solid masonry walls via capillary action from ground sources. This is often referred to as 'rising damp.' While some traditional buildings may include rudimentary damp-proof courses of slate, glazed ceramics, Roman cement or other materials, many do not, meaning there is a natural transfer of moisture from the ground level into the lower section of the wall. In all cases, it is important, prior to undertaking works to improve energy efficiency, to rectify any issues with rainwater goods, drainage and ground levels around the foot of the building to ensure that all standing water is dispelled a safe distance from the base of the walls. It is important to note that some proprietary systems may not be appropriate for use and can be detrimental to the traditional building fabric.

Surface condensation is often mistaken for rising damp and the resolution is very different, therefore it is important to ascertain which is present before deciding on the remediation required. Surface condensation typically accounts for up to 90% of instances of damp found at the base of walls in traditional buildings. This is the result of heat loss through the floor and wall, combining to produce excessive low temperatures at the floor/wall junction. As the wall is coldest here, it attracts condensation. The solution may be to raise the temperature of the wall locally either by insulating the junction externally below ground level or insulating the wall internally. Traditional means of achieving this include the use of wainscoting. Where capillary movement of moisture from the ground is present, the solution may be to reduce the amount of standing water or hard landscaping in contact with the wall by the use of a French drain around the perimeter of the wall. The external percolation medium used for this can be foamed glass insulation chips wrapped in geotextile membrane, which serve to reduce the potential for surface condensation internally by raising the temperature of the floor/wall junction.

Excess damp can also be a result of water ingress due to failed, blocked or deficient gutters, downpipes or gullies. Where such a building has had a relatively vapour-tight layer applied internally or externally at some point, e.g. cement render or gypsum plaster with vinyl paint, it is common to see vapour pressure on these layers causing debonding and the blistering of finishes. In such cases the removal of these vapour-closed layers is necessary, and the walls need to be allowed to dry out before more appropriate vapour-permeable materials (e.g. traditional or insulating lime renders/plasters, wood-fibre and calcium silicate boards) are applied. Any moisture ingress issues should be addressed, and the building fabric allowed to dry out sufficiently before an appropriate insulation is applied. Allowance for drying out needs to be made within project timeframes as part of any upgrade works involving buildings where damp is present.

Further guidance on damp and remediation measures can be found in the Advice Series *Maintenance: A guide to the care of older buildings*.[35]

Prior to the consideration of internal or external wall insulation, it is advisable to commission a condensation risk assessment to assess the risk of interstitial moisture accumulation post-application.[36] Interstitial condensation may occur when warm moist air hits a cold surface within the thickness of a building element and produces a 100% relative humidity condition. This can be predicted via interstitial condensation risk analysis in accordance with I.S. EN ISO 13788:2012 or hygrothermal analysis in accordance with I.S. EN ISO 15026:2007. Conditions for mould growth can be present at the interface of two layers or components within the thickness of a building element at temperatures and conditions significantly less critical than the dew point temperature (when liquid moisture will condense). Where mould is present within the thickness of a building element, mould spores may be introduced to the internal environment, which can affect the health of occupants and must be avoided.

Where condensation results in water accumulation, insulation materials may become wet, resulting in decreased thermal performance, as well as risk of slumping or degradation. Where condensation occurs in the original building fabric, walls may retain excessive moisture levels and degradation of mortars may occur. Such elevated moisture levels in the wall may expose it to risk of frost heave or surface spalling. Any timbers built into the original walls (rafters, joists, wall-plates, window frames, lintels, noggins, etc.) will also be at high risk of fungal and insect attack under those conditions.

Dew point is the temperature to which air must be cooled for water vapour to condense into liquid form.

Relative humidity is the ratio, expressed as a percent, of the moisture content of the air, relative to the amount of moisture that would be present if the air were saturated. As the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. Warm air can hold more moisture than cold air.

[35] Government of Ireland (2007a)

[36] See also TGD L, Appendix B3 for a detailed description of the analysis required

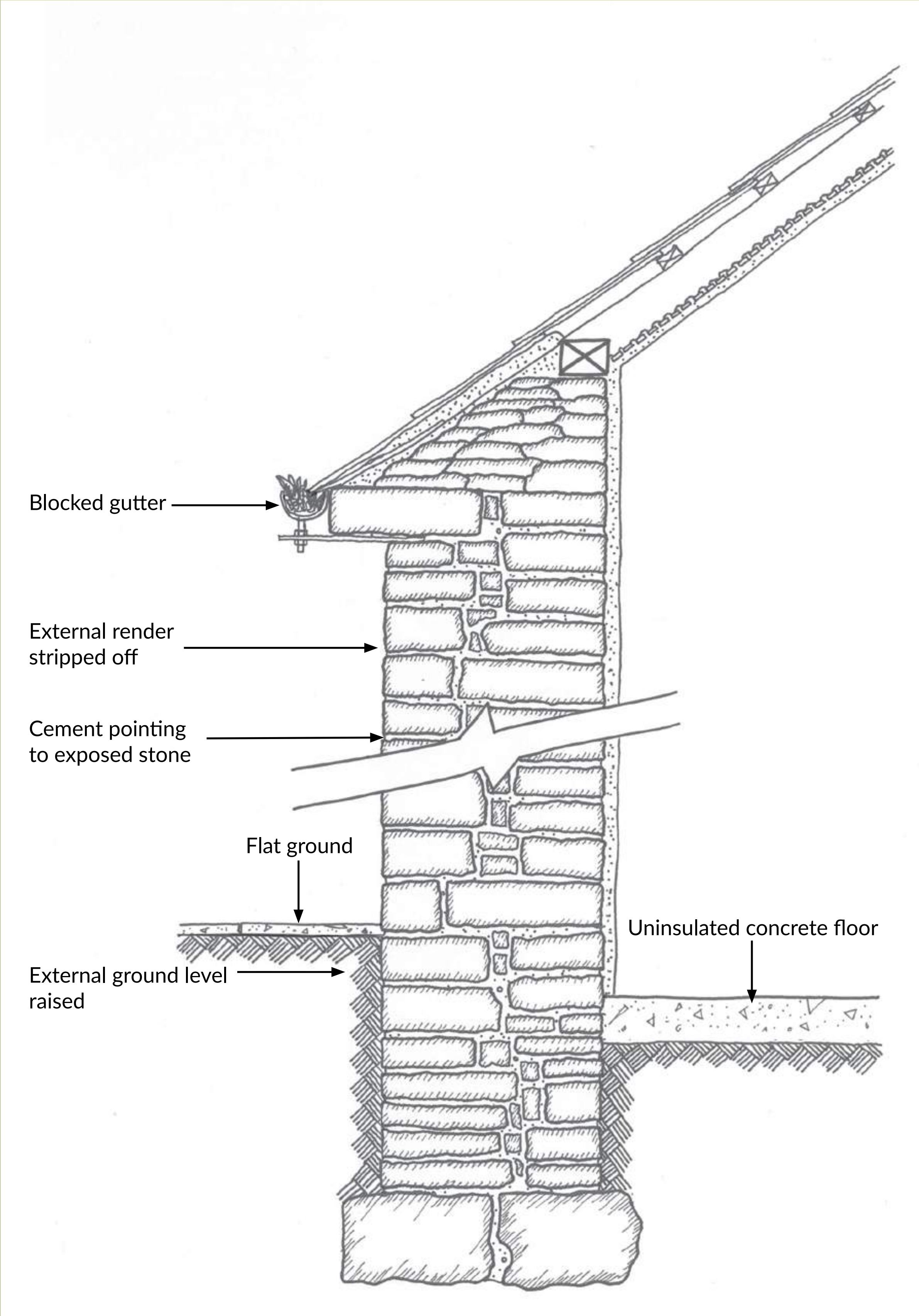


Figure 8: A traditional solid wall threatened by previous inappropriate modifications and poor maintenance

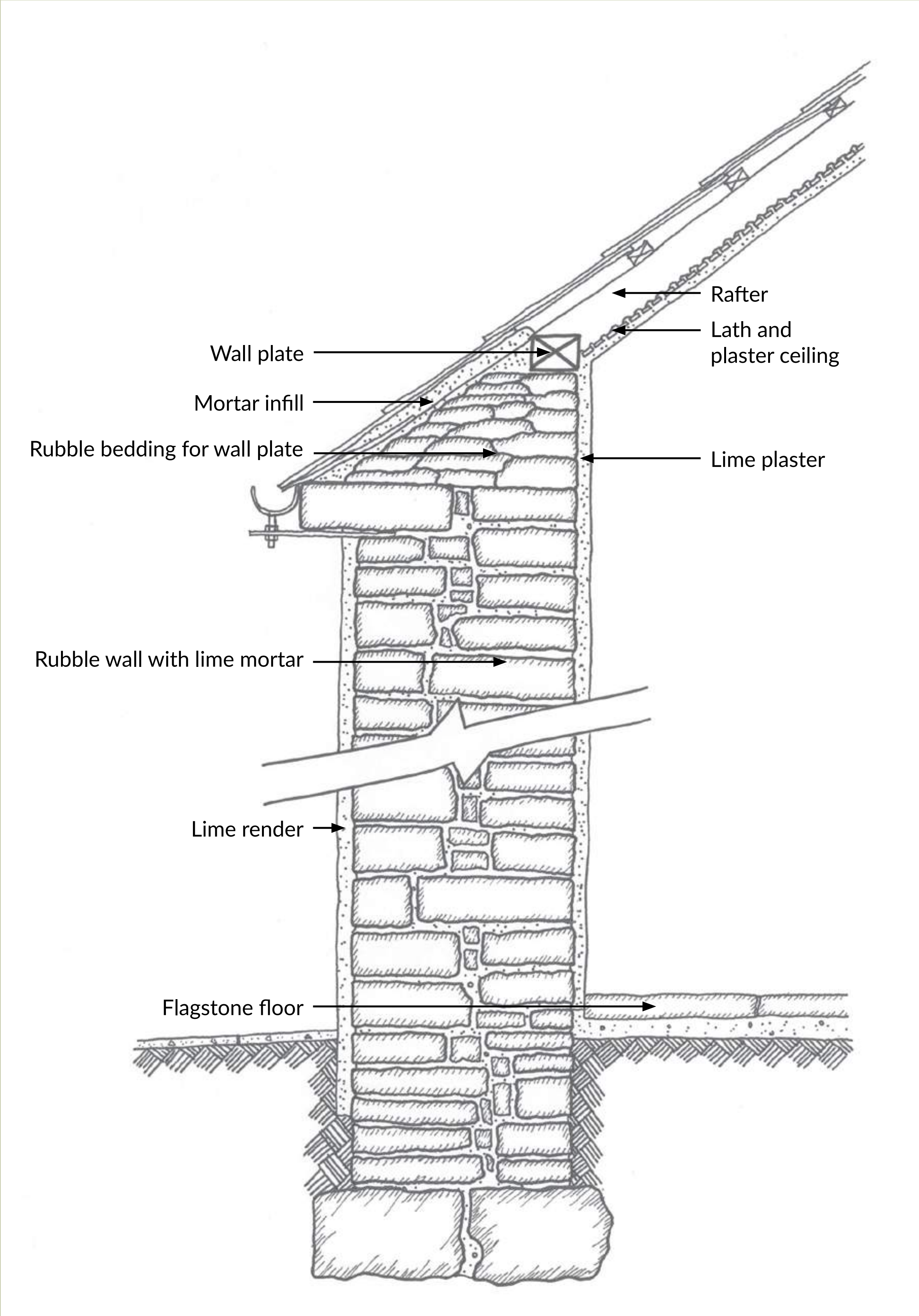


Figure 9: A well-maintained solid wall that achieves a healthy moisture balance

Figure 10: Thermal image showing additional heat flow at vertical and horizontal junctions with the abutting walls and floor. Note that the corner is the coldest point because it loses heat in three dimensions

2.1.3 Thermal Bridging

Thermal bridging is described as any area in which the otherwise uniform flow of heat from the warm to the cold side of a building element is altered due to changes in the fabric geometry, changes in material properties or penetrations of the thermal envelope. In simple terms, for a square metre area of any wall, the internal and external areas are the same and heat flow is therefore perpendicular to the internal surface, the path of least resistance for heat flow. However, where two walls meet at a corner, or (as below), two walls meet a floor, although the construction of the wall itself may be perfectly continuous, the outer wall area is now greater than the inner wall area, allowing more heat flow outwards than is being put into the wall. This constitutes a thermal bridge, as the heat flow is no longer perpendicular to the inner surface. This L-shape creates an increased heat flow through the wall abutment junction, which in turn leads to lower temperatures at the vertical corner than on the adjoining wall areas.

The additional heat losses at junctions between building elements, whether resulting from discontinuity of insulation or resulting from building geometry, are called linear thermal bridges, and are described by linear psi-values, measured in watts per metre-kelvin (W/m.K).

Thermal bridges can also be caused by penetrations through the thermal envelope, such as steel beams or metal fixings. Where the penetrating element has a higher thermal conductivity (W/m.K) than the building element it penetrates, the additional heat flow results in a point thermal bridge. Point thermal bridges are described by chi-values and measured in units of watts per kelvin (W/K).

It is unlikely that thermal bridging can be completely avoided, but the following steps may be useful to reduce the effect of thermal bridging on heat losses and condensation risks, as follows.

- Isolate the thermal bridge through insulation: use a layer of insulation locally to minimise direct contact of the thermal bridge with either the inside or the outside temperature.
- Change the thermal bridge geometry: reconfigure the geometry, or reduce the size of the thermal bridge component to minimise heat transfer.
- Increase the thermal bridge path: increase the length of the heat flow path in the thermal bridge or strategically place insulation in order to make the heat travel further to escape; and/or
- Change the thermal bridge materials: change the material causing the thermal bridge to a less conductive one.

To reduce the risk of surface condensation and mould growth as part of complex or potentially high-risk energy upgrading works, it is recommended to carry out thermal bridge modelling of the junctions and associated planar elements. Thermal bridge assessment is carried out in accordance with I.S. EN ISO 10211:2017 and BR 497.[37] The model can determine total heat flow through a section of the building envelope, which can then be used to calculate

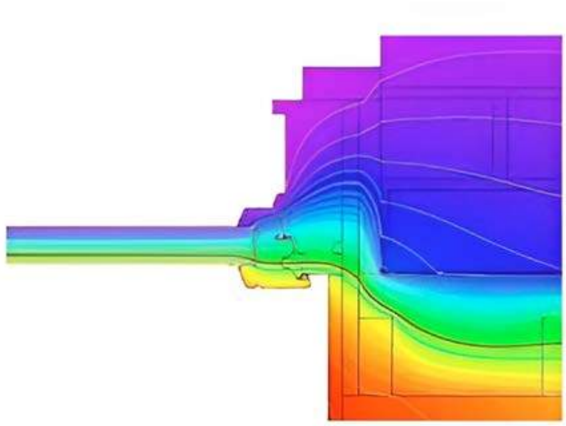


Figure 11: Thermal bridge modelling using validated proprietary software

the additional heat loss at the junction, as well as measuring critical internal surface temperatures.[38]

In complex situations, it may not be possible to avoid gaps in insulation continuity; for example, when internal wall insulation cannot be wrapped around the window reveal. In such cases, thermal modelling will be required to prove that any discontinuity does not present an increased risk of mould growth, resulting in a new or greater contravention of building regulations. Thermal modelling can be used on all types of construction, regardless of age, to check for increased local surface condensation risk.

2.1.4 Airtightness, Ventilation, and Indoor Air Quality (IAQ)

As more emphasis is placed on improving the insulation and airtightness of traditional buildings, greater attention and care needs to be given to ventilation and IAQ. Airtightness, ventilation and IAQ are interdependent, and each building retrofit plan should address them as such.

Without adequate ventilation, increased airtightness can lead to a build-up of unhealthy levels of moisture and other indoor airborne pollutants. The sources of IAQ issues are manifold, but primarily include elements produced directly by occupants (e.g. heat, carbon dioxide and humidity), elements produced within the building from activities or materials (e.g. heat, moisture, combustion gases, cooking fumes, off-gassing from new furnishings, carbon monoxide, volatile organic compounds (VOCs), particulate matter (PM)2.5, mould spores, mites and microbes), and elements produced externally that are introduced into the building (e.g. VOCs, PM2.5, ozone, nitrogen dioxide and pollen). Many of these elements are odourless, colourless and not perceptible to most people,

[37] Ward et al (2016)

[38] Technical Guidance Document L, Appendix D

Air-permeability and Air-changes Per Hour (ac/h)

Air-permeability ($m^3/m^2.h$) is used to describe the airtightness of a building under test conditions, with a pressure differential of 50 pascals (Pa) across the building envelope, using a fan and pressure sensors. The value is measured in units of $m^3/m^2.h$, where the m^3 value is the volume of air passing through the fan to maintain the required pressure differential and the m^2 value is the internal area of the airtight envelope of the building; this is measured in volume (m^3) of air passing through the building fabric (m^2) each hour (h). The larger the volume of air passing through the building fabric per m^2 of the airtight envelope per hour, the leakier the building is. The lower the value is, the more airtight the building.

Air-changes per hour (ac/h) is used to discuss airtightness results for pressure testing of buildings. The key difference is that the value is not referenced against the area of the airtight envelope of the building. Instead, the volume of air being delivered per hour by a fan, maintaining a steady pressure of 50 Pa, is divided by the volume of the airtight envelope. This determines how many times per hour the air in the building is completely exchanged. For example, if a fan is delivering $500m^3$ per hour, and the building has a volume of $250m^3$, the air-change rate is 500/250 = 2ac/h.

but they can have negative impacts on the health and wellbeing of occupants as well as the building fabric.

2.1.4.1 Airtightness

The greater focus on airtightness has in part been driven by the requirement for major renovations to comply with TGD L of the Building Regulations, which stipulates an upper limit to acceptable air permeability ($m^3/m^2.h$). Greater airtightness can lead to an improved BER due to reduced heat losses from infiltration, which is also desirable. What is often overlooked is the necessity of airtightness to prevent the movement of moist air via convection through the building fabric or at junctions between building elements leading to interstitial condensation risk.

Contrary to popular belief, leaky construction is not an inherent feature of traditional buildings but is a consequence of the longevity of the building and may have occurred due to shrinkage, settlement, alterations and repairs, wetting/drying cycles and occupants' actions over the lifetime of the structure, all inducing unintended cracks and creating air pathways. Traditional construction can achieve high levels of airtightness without danger to the building fabric. In fact, traditional diffusion-open materials such as wet lime plaster can achieve very high levels of airtightness while also reducing interstitial condensation risk. The annual application of limewash, ritualised in many rural communities, was an effective means of reinforcing the external airtight layer on traditional Irish cottages.

Airtightness is an important consideration when installing any type of insulation as the effectiveness of insulation is reduced if heat can simply escape through gaps in the building envelope and bypass the insulation, a process known as 'thermal bypass'. Furthermore, when warm air is allowed to leak out, the moisture in the air can be carried to colder parts of the building fabric where it may condense, leading to interstitial moisture build-up and increased risk of long-term damage to the building fabric. It is therefore important that airtightness improvements are considered in every energy-upgrading project, notwithstanding the requirement to ensure that adequate ventilation levels are achieved in order to ensure a healthy, hygienic and comfortable environment for building users. It should also be noted that incidental air infiltration via the fabric should never be factored into any design or retrofit plan as a means of ventilation provision.

Airtightness testing in accordance with I.S. EN ISO 9972:2015 by a tester registered by the NSAI is highly recommended for all energy-upgrading projects as both an energy-efficiency and a retrofitting quality check. An experienced NSAI-accredited airtightness tester will be able to pinpoint areas of excessive air leakage through the building fabric where excess interstitial condensation may occur. A smoke machine, micro-anemometer or thermal imaging camera can be used to pinpoint where hidden air leaks are occurring. Once leak locations are identified, these can be sealed or addressed appropriately.

2.1.4.2 Ventilation

Ventilation is the purposeful supply of fresh outside air and the removal of stale indoor air to or from conditioned spaces within a building. The ventilation may be provided by natural or mechanical means and is characterised by a controlled exchange of air as opposed to uncontrolled leakage of air through gaps and cracks in the building fabric. The ventilation system (mechanical or natural) should be capable of providing satisfactory IAQ for occupants at all times. Traditional buildings were intended to be ventilated by the daily manual opening and closing of windows and doors.

Figure 12: Limewash on traditional farm buildings

When a traditional building is made more airtight as a result of retrofit measures, adequate controlled ventilation should be introduced and maintained to ensure good indoor air quality, in accordance with TGD F, 2019 and S.R.54. Examples of typical measures that will impact on existing ventilation provision include where:

- window seals are installed
- roof and floor insulation is installed
- chimneys are blocked from use.

In addition to providing a healthy indoor environment, adequate ventilation and the removal of excess indoor moisture is important to protect the building fabric. Internal temperatures and relative humidity levels are directly related; decreasing temperature will increase relative humidity and vice versa. This explains why it is common to see condensation issues in buildings that are under-heated and under-ventilated. Improving energy efficiency can improve both living conditions and the condition of the building fabric. However, it is important that energy efficiency measures be carefully considered to ensure that they do not inadvertently contribute to condensation and poor IAQ.

Energy-inefficient buildings may sometimes be under-heated because the cost of maintaining acceptable internal temperatures is considered prohibitive. This can result in condensation leading to persistent damp conditions in the building fabric. These can have a negative impact on the long-term condition of the building fabric and on the health of occupants.

TGD F provides guidance on purpose-provided ventilation for buildings and S.R. 54 provides specific additional guidance on ventilation for renovations to existing buildings. Adequate ventilation, limiting the moisture content of the air within the building and the concentration of harmful pollutants, can be achieved in a number of ways.

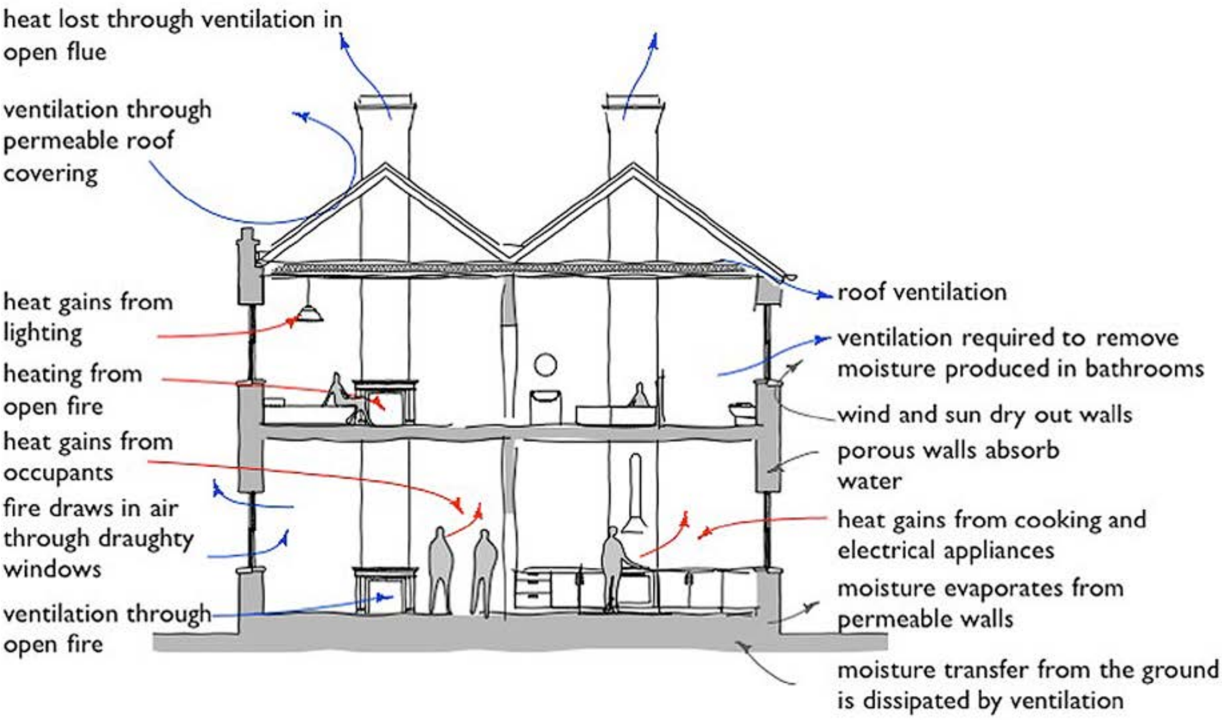
Ventilation to achieve the objectives set out in TGD F may be achieved through the supply or extraction of air by mechanical means or by natural ventilation, or by a combination of these methods, and is based on the following general strategy.

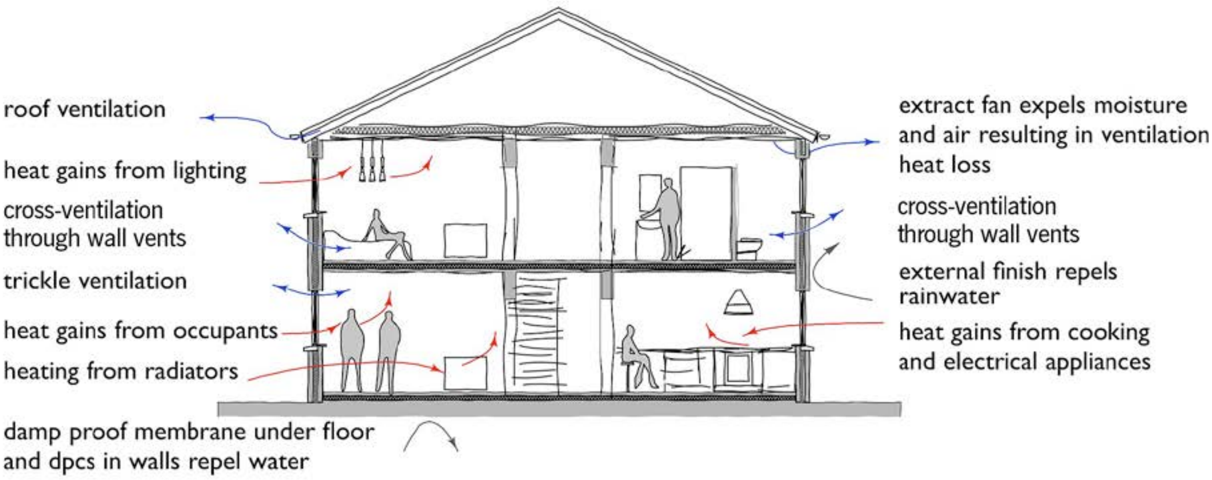
- **General ventilation** to provide fresh air to the building and remove water vapour and other pollutants that are released throughout the building (e.g. by building materials, furnishings, the presence and activities of occupants) and to dilute and disperse residual water vapour and pollutants. General ventilation provides nominal continuous air exchange. The ventilation rate may be reduced when the building is not occupied.
- **Extract ventilation** from rooms or spaces where most water vapour and/or pollutants are released, e.g. where activities such as cooking, bathing or photocopying take place. The purpose of extract ventilation is to minimise the spread of water vapour and/or pollutants to the rest of the building. Extract ventilation may be intermittent or continuous, depending on the nature of the activities involved.
- **Purge ventilation** applicable throughout the building to facilitate removal of high concentrations of pollutants or water vapour that may develop from time to time, e.g. from occasional activities such as painting and decorating and from accidental occurrences and spillages.

It should be noted that in protected structures, buildings in ACAs and other historic buildings, the addition of openings in walls or vents to windows, doors or roofs may not be acceptable and planning permission may not be granted. In these cases, well-designed mechanical ventilation may provide an effective solution. Guidance should be sought from the local authority's architectural conservation officer with regard to the ventilation options before any works are commenced.

Mechanical extract ventilation is commonly available in small units. Perimeter inlet vents can be concealed in window surrounds and operated automatically on humidity sensors. These supply demand-controlled ventilation to rooms and are balanced by a centralised extract unit located in an attic space discharging through a slate vent or a chimney.

Heat recovery systems with efficiencies as high as 90% are commonly available in the Irish market. These can be ducted or non-ducted. They can deliver savings in heating costs by recovering heat from the exhaust air to provide tempered fresh air in lieu of cold fresh air. The energy savings far outweigh the costs of running such systems, due to the efficiencies of fans in use. Mechanical





Figures 13 and 14: Comparison of the ventilation and heating requirements for a traditional building (top) and a modern building (bottom) (Images from *Advice Series: Energy Efficiency in Traditional Buildings*, 2010)

systems that allow filters to be used to remove pollutants from the incoming 'fresh' air are widely available and can significantly improve IAQ in both urban and rural areas.

In all buildings where airtightness is below $3m^3/(m^2.h)$ at 50Pa, mechanical ventilation is required.

The provision of ventilation and maintenance of good indoor air quality require careful planning and consideration, therefore a ventilation system designed and installed in compliance with TGD F should be considered as part of any retrofit strategy. Where mechanical ventilation systems are installed, these should incorporate control indicators to inform the occupant that the system is operating correctly and advise when a fault has occurred. Control indicators should be in a location visible to the occupant and not in a remote location such as an attic.

Further guidance on determining the most suitable ventilation strategy is provided in *S.R. 54:2014 & A1:2019 – Code of Practice for the Energy Efficient Retrofit of Dwellings*.

2.2 Performance Assessment Methods

A number of non-destructive techniques are available to assess particular aspects of the energy efficiency of existing buildings. These range from the use of simple handheld devices such as moisture meters and borescopes to more complex and expensive methods such as thermal imaging. Expert knowledge and experience may be needed to decide which assessment method is appropriate in a particular case, to undertake the assessment and to interpret the results. A contractor experienced with traditional buildings or a conservation expert should be able to advise on appropriate assessment methods.

2.2.1 Thermography

Thermography, or thermal imaging, is photography using a camera that captures infrared (IR) light rather than the visible light captured by a standard camera. The image produced by an IR camera is multicoloured, with each colour representing a different temperature. Thermography has many varied applications in different disciplines and can be a useful tool when assessing the condition of a building. It has particular advantages for investigating historic buildings as it is a non-invasive, non-destructive method.

Thermal imaging can be used to identify concealed problems with a building's fabric. When one is looking at traditional buildings, thermal imaging might be used to identify areas of dampness and to locate thinner depths of wall, different construction substrates, cracking and voids. Expertise is required both in deciding how and when to capture IR images and subsequently in interpreting the information. For example, objects that have high or low emissivity, such as metal, do not give an accurate temperature reading. Weather conditions, orientation and the time of day that the image was taken all have the potential to affect the reading, as does the difference between internal and external temperatures. The information gathered from thermal images can only be properly assessed in conjunction with data gathered as part of a comprehensive condition survey and with the application of specific expert knowledge of historic construction technologies.

2.2.2 Air Leakage Testing

Air leakage testing, or fan-pressurisation testing, assesses the airtightness of a building and the rate of air leakage occurring through the fabric. Testing a building's airtightness may highlight areas or points of particularly high, uncontrolled air leakage that could be remedied without compromising the long-term health of the building fabric.

2.2.3 Endoscopy or Remote Visual Inspection

Inspections of concealed parts of a building's construction can be carried out using a borescope or fibrescope camera, generally with minimal disruption to the building. This type of inspection can be used to investigate walls, roofs and floors for hidden defects by inserting a scope into a small inspection hole. In a protected structure, the drilling of an inspection hole should be carried out with care and a location should be chosen that avoids any adverse impacts. In some cases, drilling through the building fabric may be unacceptable.

Such an inspection can be used as a follow-up to a thermographic survey to investigate the exact cause of heat loss through a particular part of the building fabric. The results of the inspection can be photographed or videoed on a camera attached to the system.

2.2.4 Radar

Examination of a building with radar uses low-power radio pulses to determine the make-up and condition of a structure. It can be used successfully on most construction materials to locate and measure voids, cracks, areas of corrosion and discontinuities in walls or floors and to detect the presence of old chimney flues. The use of radar is a relatively expensive and complex assessment method that requires expertise to undertake and to analyse the resulting data.

2.2.5 Ultrasound

Ultrasonic scanning involves the use of high-frequency sound waves to provide a cross-section through a material. It can be used across very fragile surfaces without causing damage, which makes it particularly suited for use on sensitive historic buildings. This non-destructive technique can be used to determine if any

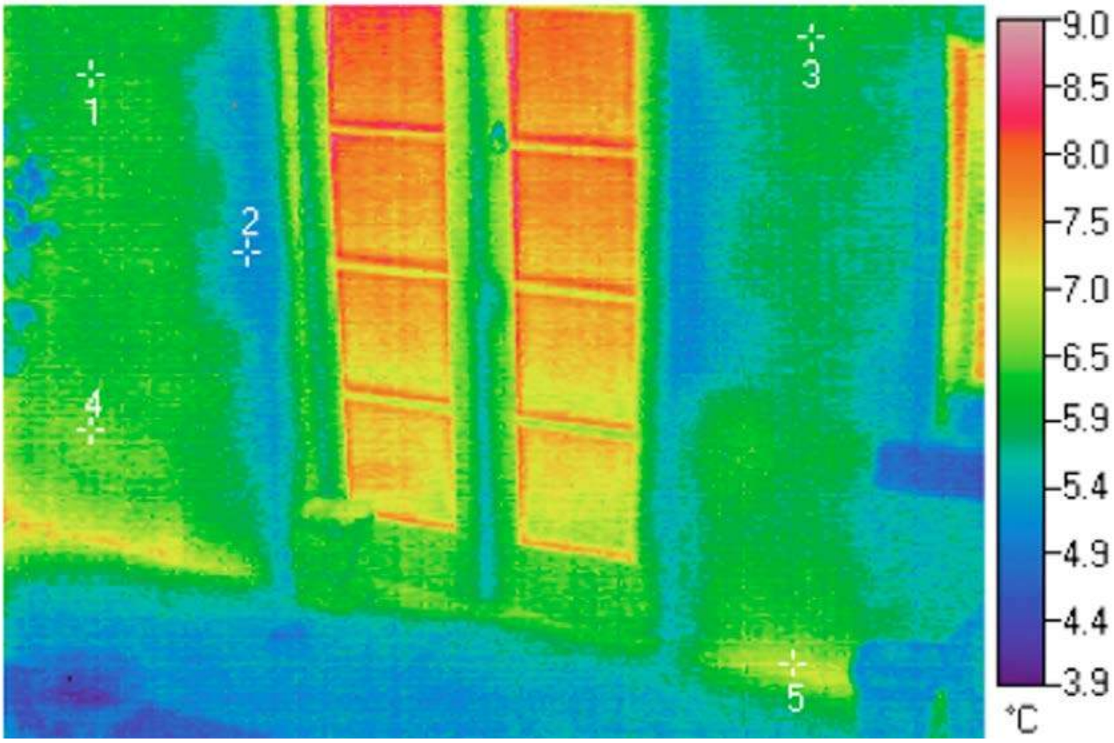


Figure 15: A thermographic image of a double-glazed door at semi-basement level in a nineteenth-century terraced house taken from outside; note how the yellow patches at the base of the wall, which are damper, indicate that these areas are emitting heat (possibly from an underfloor heating system) at a higher rate than the rest of the wall (Image from *Advice Series: Energy Efficiency in Traditional Buildings*, 2010)

decay is present in structural timbers and, if so, its extent. It can also be used to assess the structural integrity of timber joints and the presence of zones of weakness within stone blocks. A high level of skill and experience is needed to carry out the assessment and interpret the results.

2.2.6 Indoor Air Quality Monitoring

IAQ monitoring is carried out to collect data on the level of harmful pollutants within the internal environment of a building. Indoor air can be five times more polluted than outdoor air and is 200–500 times more likely to carry carcinogens. There are a number of commercial monitors on the market but, in general, parameters measured include:

- temperature (°C)
- relative humidity (%)
- particulate matter PM2.5 (μg/m^3)
- carbon dioxide (ppm)
- volatile organic compounds (ppb)
- ozone (ppb)
- nitrous dioxide (ppb)
- radon.

It is recommended to monitor IAQ during an occupied state both before and after retrofit works for a period of no less than one month. The pre-retrofit findings should inform the ventilation strategy for the building.

2.2.7 Calculating and Measuring U-values

U-values are used to describe the thermal performance of building elements and are part of the base data used to assess the energy performance of whole buildings.

To calculate the U-values of different building components and elements, the material characteristics of the building element are required. Each building element (e.g. wall, roof or floor) usually consists of a series of layers, each with a known thermal conductivity, making the calculation of U-values using validated software relatively straightforward. Numerous software packages exist to do this. The method for calculating U-values of building elements and components is specified in I.S. EN ISO 6946:2017. The method for calculating U-values of components involving heat transfer to the ground, e.g. ground floors and basement walls, is specified in I.S. EN ISO 13370:2017. Further guidance on calculating U-values and a list of default values for common building materials can be found in Appendix A of TGD L.

In general, the first step is to establish the thermal conductivity (W/m.K) of each material in the construction using certified material data. Where data on the exact building material is not available, either petrographic analysis can be conducted or a material within the software database with the most similar properties should be selected, provided it gives a conservative value. For new materials, such as insulation, data can be found through the product's Agrément Certificate or Technical Data Sheet to establish certified data in compliance with the Construction Products Regulation and TGD D. Core samples and/or lab analysis may be required if the material properties of the building element are unknown.

The U-value does not take account of orientation or exposure. These are accounted for in the DEAP/NEAP energy balance calculation through the calculation of solar gains and losses through glazing and by the air permeability rate. Heat loss calculations do not adjust for material defects, such as dampness, as these are assumed to have been addressed before any upgrading works take place. Thermal modelling of documented wall build-ups showing the combination and proportion of specific known

materials (e.g. lime mortar, limestone, air) can also be used to derive U-values in accordance with I.S. EN ISO 6946:2017.
Research on U-values has shown that software programmes for U-value calculation tend to underestimate the thermal performance of existing structures compared with the results from in-situ measurements.[39] Other research casts doubt on the accuracy of in-situ U-value measurement, with evidence of variances of −14% to +43%.[40] Where in-situ U-value assessment is undertaken, it should be done in accordance with ISO 9869-1:2014. However, in the absence of acceptance of the ISO 9869 methodology by the European Commission, in-situ U-values are currently not an acceptable source of data for demonstration of compliance with TGD L or for use in BER calculations.

Figure 16: In-situ U-value measurement kit installed on the internal face of a wall (note that the presence of wallpapers may distort the reading)

[39] Baker (2011)
[40] Asdrubali et al (2014)
[41] May et al (2017)

2.3 Potential Health Risks

As with any construction project, it is important to consider how the building fabric and systems may be affecting the health of the occupants. Improved airtightness, for example, can unintentionally exacerbate pre-existing maintenance issues, so it is important to identify and rectify the cause of these defects before any energy upgrade.

An introduction to some of the more common health risks within traditional buildings is provided below.

2.3.1 Mould

High levels of relative humidity within a building can arise from any activity that generates moisture, such as cooking, showers and clothes-washing or drying, and can increase indoor humidity levels. Persistent high humidity levels can result in condensation and mould growth, particularly in poorly ventilated or unheated parts of a building. The long-term presence of mould in buildings can have considerable and sometimes very serious negative impacts on occupant health, most notably through respiratory illnesses.[41]

Mould growth in buildings depends on many factors, including internal temperature, external temperature, relative humidity and a building's design and construction. Mould growth can be expected to occur within a period of 3–5 days where conditions of 80% relative humidity occur on a surface, if that surface can support mould growth. Given that mould requires certain conditions to grow, the risks can be largely minimised through good fabric design or by the proper management of a building. Relative humidity can usually be regulated with adequate heating and appropriate ventilation. Humidity

Figure 17: Mould growing behind shutters

detectors can be helpful in identifying areas at risk and to encourage manual ventilation or to automatically operate mechanical ventilation systems.

The first signs of mould growth are typically seen at locations of thermal bridging, where the internal surface temperatures are lower. This can be compounded by any deficiencies in the building fabric or a lack of air movement at internal corners and behind curtains, built-in furniture, shutters, etc. A reduction in warm air convection across a surface lowers the surface temperature in these locations compared to the more exposed planar elements around them, which creates a cooler place for moisture to condense.

Some materials do not support the growth of mould, and some indeed resist mould growth

Figure 18: Extreme case of moisture ingress due to poor maintenance

by virtue of their pH, e.g. lime plaster. Where a material does not support mould growth, it is still possible that internal surface condensation (i.e. water formation) can occur at the surface where 100% relative humidity is reached. TGD L, Appendix D provides guidance on how to assess the risk of surface condensation and mould growth. TGD F provides guidance on limiting condensation and mould growth through adequate ventilation. Thermal bridge modelling and hygrothermal risk analysis may be employed to design out the likelihood of surface and interstitial condensation, respectively associated with specific energy-upgrading measures.

2.3.2 Radon

Radon is a naturally occurring radioactive gas that can cause lung cancer in persons exposed to high levels over a long period. It is formed in the ground by the radioactive decay of uranium that is present in all rocks and soils. It is not visible to the naked eye, has no smell or taste, and therefore can only be measured with special detectors. Radon is the cause of approximately 350 cases of lung cancer in Ireland each year.[42]

As buildings tend to have a slightly lower indoor air pressure compared to that in the ground, radon can be drawn up from the ground into the building. Ingress routes for radon gas are usually cracks and holes in floors and walls, and gaps around service pipes and cables. Radon from domestic water sourced from ground water, gas supplies and building materials can also contribute to the indoor radon concentration in a building but, in most cases, the contribution is considered minor when compared to the soil gases in the ground on which the building is constructed.

Radon testing before and after the retrofit of a building is recommended. A map of radon hotspots in Ireland can be used to indicate a potential risk,[43] but high radon concentrations in buildings are not limited to these areas and it is highly recommended that radon testing be carried out as part of any retrofit project regardless of the building's location. Radon tests are inexpensive and, as retrofit works often improve the airtightness of the building, it is very important to ensure that post-retrofit radon levels remain at a safe level. It is not possible to predict the efficacy of any particular radon control measure, therefore radon testing, before and after the renovation works are complete and when the building is fully occupied, is needed. It is the only reliable way to establish the radon exposure levels of occupants. The procedure for monitoring radon in homes and workplaces can be found in the relevant Environmental Protection Agency (EPA) guidance.[44]

Where an initial test indicates a radon level above the 200Bq/m^3 (houses) or 300Bq/m^3 (workplaces) national reference level, a radon protection strategy should be included in the retrofit design strategy. Section 2 of TGD C provides information on appropriate radon protection measures where new ground-bearing floors are installed.

2.3.3 Asbestos

Asbestos is a fibrous, naturally occurring mineral that is a Category 1 carcinogen and has been linked to an increased risk of asbestosis, lung cancer and mesothelioma (cancer of the cells that make up the lining of organs). All forms of asbestos present health risks if persons are exposed to it over extended periods.

Asbestos-containing materials (ACMs) were banned for use in buildings in Ireland in 2000, therefore it is advisable to commission an asbestos survey prior to invasive works on

42 More information on radon gas can be found here: www.radon.ie

43 Radon Map, EPA: www.radon.ie/maps

44 EPA Radon Testing: https://www.epa.ie/environment-and-you/radon/radon-testing/#d.en.82887

Figures 19, 20, 21: Examples of where asbestos can be found in a traditional building – panels of corrugated roof sheeting, floor tiles and roof tiles

buildings constructed or refurbished before that date. Asbestos was used in building materials and consumer goods, particularly to resist heat and give fire protection. Other common uses for asbestos include, but are not limited to:

- insulation lagging in buildings and factories, on pipework and for boilers and ducts
- insulating boards used as wall partitions, fire doors, ceiling tiles, etc.
- cement products such as sheeting on walls and roofs, tiles, cold water tanks, gutters and pipes and in decorative plaster finishes
- spray coatings on steel work, concrete walls, and ceilings, for fire protection and insulation.

Asbestos materials can be inadvertently disturbed during the maintenance, repair or refurbishment of a building. Drilling, cutting or other disturbance of existing asbestos materials can release asbestos fibres into the air. The presence of asbestos fibres in finished products is not obvious and the different types of asbestos cannot be distinguished by their visual appearance or colour. Laboratory analysis is required to identify the type of asbestos. If a building does not have any record of an asbestos survey or is derelict, it is advisable to engage a specialist asbestos surveying company. The Health and Safety Authority (HSA) provides guidance on asbestos and should be consulted if the presence of asbestos is suspected in a building.[45] It is also advisable that all persons specifying and working on the refurbishment of buildings constructed prior to 2000 undertake an HSA-approved asbestos-awareness training course.[46]

Some typical places where asbestos can be found are shown in Figures 19, 20 and 21, but it should be noted that this does not show all possible uses and locations of ACMs. A detailed survey will be required at the outset of a project to identify all ACMs present in a building.

2.3.4 Lead

Lead is a toxic heavy metal found in many products and materials used in traditional and historic buildings. It is commonly found in flashing around chimneys, roof ridges and valleys, rolled metal sheeting, paints, metal solders, lead piping and jointing and some rubber compounds.

Lead poisoning can occur through inhalation of lead particles, fumes or vapours or by ingestion (swallowing) of lead particles. Lead-based paints were widely used in traditional buildings up to 1988, when their use was restricted by the introduction of the European Communities (Protection of Workers) (Exposure to Lead) Regulations, 1988. They present particular risks when heat is applied during removal and may, where appropriate, be best left in place.

Lead poisoning can occur through acute high-level exposure or through long-term low-level exposure. Where present, lead pipes should be replaced with suitable non-toxic alternatives to protect the health of occupants and the building fabric from sudden failures of the lead. The presence of lead in paint and other products/materials can be confirmed by specialist laboratory testing.

Further details on lead-containing materials, exposure risks, necessary precautions and relevant legislation can be found in the HSA publication *Safety with Lead at Work: A Guide for Employers and Employees*.[47]

45 HSA (2013)

46 Asbestos Safety for Tradespeople CPD: https://hsalearning.ie/mod/page/view.php?id=262

47 HSA (2014)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Chapter 3

Specifying Safe and Effective Energy-Upgrading Measures

This chapter discusses:

- recommended steps to follow when developing a comprehensive retrofit strategy for a traditionally built building and what should be completed prior to the start of retrofit works
- recommended materials for retrofit works on traditional buildings
- preparation and installation measures for the upgrade of roofs, floors, windows and doors, as well as solid walls
- other non-fabric efficiency measures that are low cost and easy to implement

3.1 General Principles

This chapter provides guidance on developing an energy-upgrading strategy and on the retrofit materials and measures that are typically suitable for traditional buildings. This is general guidance and, as every building is different, the recommendations may not be suitable for all cases. It is up to the building professional to use their best judgement and to enlist specialist advice when required. Consideration should be given at an early stage to which measures would require planning permission and/or would trigger a 'major renovation' under TGD L. It should be noted that, in the case of a protected structure or proposed protected structure, many measures may require planning permission and, in such cases, advice from a local authority's architectural conservation officer should be sought at the outset of the project.

A holistic or whole-building approach to energy upgrading is advisable for all traditional buildings regardless of their protection status. This will ensure that improvements to the building's fabric, heating and energy systems and the conservation of its special interest are all considered within the decision-making process. For a traditional building, the project should start with consideration of the specific conditions and hygrothermal behaviour of the building fabric. An assessment of the building's character and special interest at the outset will ensure that significant features are not inadvertently lost or damaged during the retrofit process.

The use of processes that are reversible, or substantially reversible, when undertaking works is always preferable as this allows for the future correction of unforeseen problems, should the need arise, without lasting damage being caused. A 'repair rather than replace' approach also reduces the embodied carbon associated with the retrofit works.

Outside of fabric upgrades, a number of low-cost and easily implementable measures that can improve energy efficiency and help to bring a traditional building's energy rating to a cost-optimal level, in so far as technically, functionally and economically feasible, are discussed in Section 3.5 below. Guidance on integrating low-carbon and renewable energy systems with traditional buildings is provided in Chapter 4.

3.2 Developing a Retrofit Strategy

3.2.1 Establishing a Retrofit Design Process

A standard procedure for developing a retrofit strategy for traditional and historic buildings is set out in I.S. EN 16883: 2017. The recommended procedure includes the steps necessary to identify the appropriate energy-efficiency improvements for a particular building. Not all steps will be required in every case. Further statutory requirements may apply.

Table 5: Recommended procedure for developing a retrofit plan adapted from guidance in I.S. EN 16883:2017

Step 1: Initiate the process

- Decide what the overarching objective is. It may be improved comfort, reduced energy waste/ usage, lower carbon-dioxide emissions, etc.
- Where the building is a protected structure, a proposed protected structure, or located within an ACA, assess what historic or architecturally significant features it retains.
- Consider what other statutory protections apply.
- Early, initial consultation with statutory authorities may be needed.
- Assess whether or not expertise is likely to be required.

Step 2: Assess the building

- Assess the heritage significance of the building.
- Assess the condition of the building.
- Assess whether the retrofit works are likely to be complex (see Table 6).
- (Assess the impact of past alterations – optional.)
- Address existing defects, especially where these are causing moisture ingress or damage.

Step 3: Specify objectives and targets

- Set objectives and targets based on key assessment categories and criteria such as technical compatibility, heritage significance of the building and its setting, economic viability, energy-saving, indoor air quality, impact on the outdoor environment and aspects of use (see I.S. EN 16883:2017).
- Consider whether specific/additional expertise is required (see Tables 3 and 4 above).
- Decide whether improvement of energy performance is needed (if there is no need – end the process).
- Assess whether the works constitute 'major renovation' (see Section 1.3.3 above).

Step 4: Assess and select measures for improved energy performance

- Develop long list of potential measures and assess risk.
- Determine risks relating to condensation, ventilation, thermal bridging and the impact of the measures on the building's heritage significance.

Step 5: Undertake risk mitigation measures

- Appoint specialist consultants and/or commission specialist surveys, as necessary (e.g. heritage impact assessment, thermal bridge modelling, condensation risk assessment).

Step 6: Create a short list of measures and review their impact

- Determine whether the proposed measures will meet the retrofit and energy-saving objectives and targets.
- Consider alternative retrofit measures or materials appropriate to the specific traditional building.

Table 5 *continued*

Step 7: Revise objectives and energy-efficiency targets

- Revise objectives and targets, if necessary, based on the findings of risk assessment.

Step 8: Review with the statutory authority (as required)

- Consult with the local authority's architectural conservation officer at the early stage of the design process if the building is protected or is located in an ACA.
- Consult with the local authority building control officer if the works would deviate from the building regulations.
- Review detailed specifications.
- Apply for planning permission and any other statutory consents, as required.

Step 9: Appoint suitably qualified contractors/specialists

- Appoint contractors, who should have the required skills and an understanding of, and experience working on, traditional buildings.
- Retain and/or review the need for specialist advice and monitoring over the course of the works.

Step 10: Implement, document and evaluate

- Be aware that, when working with older buildings, unexpected conditions will often emerge during the construction phase that can affect the scope of work, the choice of technical measures, costs and timeframe.
- Ensure proper handover to the building owners/occupants, including end-user training on building systems (see Section 3.2.8 below).
- Undertake post-occupancy evaluation (optional, but this is recommended for works undertaken by public bodies).

The process begins with the survey and assessment of the building – this includes both the on-site condition assessment and a desk-based assessment of the building's architectural, historic, archaeological, artistic, cultural, scientific, social or technical interest. Instances of poor maintenance (e.g. blocked rainwater goods and slipped slates) should be identified and repairs scheduled in accordance with their urgency. Maintenance defects can have a significant effect on the building's thermal performance and the fabric of the building can take considerable time to dry out before any insulation can be added.

Figure 22: Vegetation growing in a blocked hopper and downpipe

Following this, the retrofit objectives can be agreed with the building owner and specific targets determined (e.g. energy-efficiency and/or decarbonisation targets). The information gathered on-site and, in relation to the building's historic character and construction, will help to inform the extent of feasible retrofit measures and achievable retrofit targets and objectives. This should be seen as an iterative process, and it may be necessary to revise the retrofit targets at a later stage based on the risk presented to the building fabric.

Once a realistic set of targets has been set, it is recommended to draw up a long list of potential retrofit measures and assess the associated risks and impacts of each. The historic character of the building may mean that retrofit measures that would visually alter the building internally or externally may not be appropriate. Other measures may introduce unacceptable risk in terms of moisture retention, thermal bridging, and the like.

Before deciding on a short list of retrofit measures, it may be necessary to enlist the advice of a specialist or to commission specialist surveys, assessments or analyses in order to properly understand, and then appropriately mitigate, any risks associated with the retrofit works. Any measures that would present unacceptable hygrothermal risks should be excluded from the short list of measures. Consultation with the local authority can also help determine the short list of appropriate measures at this stage. Finally, detailed specifications for retrofit works can be drawn up based on the previous assessments and in the knowledge that they will not introduce any new, or greater, contravention of building regulations.

Further guidance on the aforementioned aspects of developing a retrofit strategy are provided in the following sections.

3.2.2 Assessing the Building Condition

Prior to embarking on any retrofit project, it is important to understand the building in question and, in particular, its condition. A minor investigation, which does not impact on important building fabric, to confirm and fully understand the construction of the building may be helpful. Where inappropriate alterations have been made in the past, these may need to be reversed in order to protect the fabric of the building and prevent long-term damage. Vapour-permeable insulation may not work as intended on top of impermeable materials and the latter may need to be replaced with suitably permeable materials. Care should be taken when removing render/plaster so as not to damage the underlying historic fabric.

Poor-quality modern extensions should be carefully assessed to establish if they are stressing the historic fabric or causing long-term damage and, where warranted, may best be removed. In some cases, such removals may require planning permission.

Biohazards may also be present in the form of spores and fruiting bodies of fungi, vermin or insects, which will need to be carefully treated. Other wildlife may need to be carefully removed if causing damage and only where these are not otherwise protected, e.g. birds or bats.[48]

Site investigation may also reveal ground contaminants, which will also have to be safely removed. TGD C contains a list of potential ground contaminants to be assessed in any site investigation.

48 Marnell et al. (2022)

3.2.3 Assessing Building Energy Usage

Understanding the current energy usage of a building is essential in order to set realistic energy-efficiency improvement targets. A pre-works BER assessment is recommended to gain an understanding of how well the building is performing and to identify areas for improvement. It is important, however, to ensure that the BER assessor has a good understanding of both building physics, as it applies to traditional construction, and the general retrofit guidance set out in this document.

Business and public sector organisations are currently required under the Energy Efficiency Directive (transposed into Irish law by SI 426 of 2014; SI 626 of 2016; SI 599 of 2019) to complete energy audits every four years. Further guidance on complying with the regulations is provided by the SEAI.[49]

3.2.4 Assessing Heritage Significance

Traditional buildings may be of architectural heritage interest even if they are not included on the record of protected structures or located within an ACA. An accredited conservation architect or consultant can assist in identifying significant features and advise on the protection of the building's heritage values. Further information on individual buildings may be found in the National Inventory of Architectural Heritage.[50]

3.2.5 Setting Energy-Efficiency Objectives

Standards for thermal comfort have increased greatly since the construction of many traditional buildings. The temperature at which an occupant is comfortable depends on several factors, such as air movement and humidity levels, and differs from one person to the next. It may not always be possible to bring traditional buildings up to the energy-efficiency level of new buildings and, where this is the case, traditional methods of temperature control such as installing shutters or heavy curtains on windows can improve thermal comfort without a need to increase energy use for space heating (see Table 10).

Based on the building's character and special interest and the results of the condition assessment, and with the building energy assessment in mind, expectations for the retrofit should be drawn up. Typical objectives may include:

- reduced operational emissions, fossil fuel consumption or energy consumption
- improved BER rating (e.g. to B2)
- increased use of energy from renewable energy sources
- improved U-values of the building envelope (roof, floor, walls and/or windows)
- improved airtightness
- improved indoor air quality
- embodied carbon target (tonnes of CO_2eq per m^2 of a building)

To be able to accurately assess the projected success of the retrofit, these objectives should be based on the best available data and include the degree to which it is aimed to improve the building. The aim should be to improve the energy efficiency as far as is reasonably practicable.

3.2.6 Determining Project Complexity

The retrofit of traditional buildings for improved energy performance is not without risks. These can be mitigated in most cases through the use of vapour-open materials, improved ventilation and the application of hygrothermal risk analysis and thermal bridge modelling, where required by building regulations.

[49] See https://www.seai.ie/business-and-public-sector/energy-auditing/

[50] See www.buildingsofireland.ie

Table 6: Questionnaire to assist in determining if a building or retrofit project is complex and which risk mitigation measures may be required

Question (Note: this is a non-exhaustive list)	**Yes**	**No**	**Mitigation measures**
1. Is the building a protected structure or a proposed protected structure?			
2. Is it located in an architectural conservation area?			
3. Is it subject to the National Monuments Acts?			
4. Are there signs of moisture-related problems such as dampness, staining or mould growth? These could be exacerbated by adding insulation without remediation.			
5. Are there cementitious materials or impermeable wall linings that are inhibiting the traditional vapour permeability of the walls?			
6. If internal wall insulation (IWI) is being considered, are there any traditional or historic internal features (e.g. cornices, wainscoting, shutter boxes, original lath and plaster) that are worthwhile to retain?			
7. If external wall insulation (EWI) is being considered, are there any external features or decorative details that may be difficult or impossible to insulate over, or to replicate (e.g. dentils, windowsills, string courses and decorative details)?			
8. Do the works require anything other than a standard solution using appropriately certified materials, do they involve significant specialist or bespoke repairs, or are they associated with either an orange or a red risk level in the traffic light system (see Table 9)?			
9. Do the works involve significant specialist or bespoke repairs, or are they associated with either an orange or red risk level in the traffic light system (see Table 9)?			
10. Are significant changes proposed to building services or ventilation systems likely to disrupt existing historic fabric (e.g. installing ductwork, pipework or heating systems, rewiring behind sensitive fabric elements) that is to be retained?			

An accredited conservation architect or conservation consultant should be engaged if the building is a protected structure, lies within an ACA, has historic features that are to be retained or is in an advanced state of disrepair. Specialist surveys may be required to identify and remediate other issues specific to the building or the site or to meet the objectives of the retrofit (see Section 1.4).

The first step is to determine if a building or retrofit project is 'complex', meaning that the retrofit project is likely to require specialist advice or services of some sort. The complexity of the project may be reduced through a series of mitigation measures, such as enlisting a conservation consultant or undertaking a hygrothermal assessment. Table 6 contains a non-exhaustive list of questions to help a retrofit specifier to determine whether a building or proposed retrofit project is complex and whether additional expertise, surveys or assessments may be required to mitigate risk. Answering ‘yes’ to any of these questions means the building or retrofit project should be considered complex and mitigation measures should be pursued to address the issue(s).

For instance, if the building is exhibiting significant moisture issues, appropriate risk mitigation measures may include the appointment of an accredited conservation architect or conservation consultant and the commissioning of specialist surveys, such as timber decay surveys, to identify the remedial maintenance works that may be required.

If the building or proposed retrofit works are not complex, an experienced contractor who understands traditional buildings may be sufficient to oversee and carry out the works.

3.2.7 Selecting Retrofit Measures

In all cases, there are graduated levels of intervention that can be pursued, starting with general maintenance and repair, followed by interventions that present minimal hygrothermal risk or result in minimal loss of original fabric. Non-invasive fabric measures may sometimes be the only options appropriate for some protected structures and buildings within ACAs, but that does not mean that energy and, in particular, CO_2 emission savings cannot be made. Heating, lighting, plumbing and ventilation systems are often not original to the building and may have undergone periodic changes over its lifetime. These can be upgraded to more energy- and carbon-efficient systems, often without damage to the fabric of the building. Where invasive fabric interventions are to be made, which could adversely impact on historic features that are to be retained, specialist advice and surveys should be commissioned to inform the selection of appropriate retrofit options.

Figure 23: Cast-iron radiator with a thermostatic control

The specification of certain complex retrofit measures should be supported and informed by the results of analysis, including thermal and hygrothermal analysis where these are required, to confirm the long-term impact of the proposed measures on the building fabric. These analyses can determine the suitability of the proposed retrofit measures for the existing building fabric. For example, insulation of the building should seek to ensure that the building can be heated in an economical manner, without causing long-term damage to the building fabric and without prejudicing its character.

The maintenance of acceptable temperature and relative humidity levels is key to the performance and condition of the building fabric in the long term. As such, any retrofit proposals should factor in the intended use, or likely uses, of the building at the outset and deal with the issue of appropriate ventilation.

It is important that any existing issues with moisture ingress are addressed first; otherwise the addition of insulation is likely to exacerbate the risks presented to the building fabric.

3.2.8 Preparing for Post-Retrofit Occupation

The anticipated usage patterns are built into the DEAP/NEAP calculation for each intended use of the building. Where a building is being used or returned to use as a dwelling, a number of factors will determine the actual energy use such as number of occupants, hours/duration of occupancy, and knowledge of proper building management and maintenance. These are all standardised in the DEAP/NEAP calculation to allow buildings with similar uses to be compared with each other.

On completion of the works, building owners are entitled to be provided with a Safety File covering the works, where these are above a qualifying threshold.[51]

Useful information to include in the Safety File (and/or Building Renovation Passport when this is introduced) is presented in Table 7. Consideration could be given to providing additional digital operational and maintenance guidance via QR codes attached to equipment for the benefit of occupiers.

Table 7: Information that may be included in a safety file provided to building owner

Item	Information to be included
Ventilation	Description of installed ventilation system
	Introduction to importance of ventilation for IAQ and moisture control
	How the system works and operation details – location of control indicators (should be visible)
	Maintenance requirements (e.g. filters) where relevant and where to get them
	Contact details if problem arises with system and links to manufacturer's manuals
Heating/Cooling system	Description of installed heating and cooling systems
	How the system works and operation details
	How to programme and maintain maximum efficiency throughout the year
	Maintenance requirements
	Contact details if problem arises with system and links to manufacturer's manuals
Renewable energy systems	Description of installed renewable energy system
	How the system works and operation details
	Maintenance requirements
	Contact details if problem arises with system and links to manufacturer's manuals
Lighting systems	Description of installed lighting system
	How the system works and operation details
	Maintenance requirements
	Contact details if problem arises with system and links to manufacturer's manuals
General maintenance	General maintenance requirements and frequency of replacement of components (where less than 50 years' service life is expected)

[51] HSA (2015)

3.3 Materials

Traditional buildings are most commonly built with solid walls of vapour-permeable materials, such as brick, stone, earth/clay, timber, thatch, lime mortar, lime renders or plasters, which have different levels of vapour permeability. The compatibility of new materials should be fully established to avoid any undesirable side effects. TGD L, Appendix B3 provides guidance on the means to assess the impact of adding new materials to existing building fabric by reference to hydrothermal analysis conducted in accordance with I.S. EN ISO 13788:2012 and/or I.S. EN 15026:2007 as appropriate.

In addition to reducing energy use and operational emissions, retrofit works should aim to reduce embodied carbon emissions by taking a whole-life carbon assessment approach to the selection of materials and products in accordance with the EU Level(s) methodology for calculating life cycle global warming potential.[52]

Retrofit materials or measures that have the potential to cause damage to the building's fabric or to its character and special interest should not be used.

3.3.1 Complying with Regulations

Any materials used should comply with Parts D and L. TGD D defines proper materials as materials that are fit for the use for which they are intended and for the conditions in which they are to be used, and includes materials that:

- bear a CE marking in accordance with the provisions of the Construction Products Regulation
- comply with an appropriate harmonised standard or European Technical Assessment in accordance with the provisions of the Construction Products Regulation, or
- comply with an appropriate Irish Standard or Irish Agrément Certificate or equivalent with an alternative national technical specification of any state that is a contracting party to the Agreement on the European Economic Area, which provides in use an equivalent level of safety and suitability.

In the case of material alterations or material changes of use of existing buildings, adoption without modification of the guidance in TGD D may not, in all circumstances, be appropriate. In particular, adherence to guidance including codes, standards or technical specifications, intended for application to new work, may be unduly restrictive or impracticable. Buildings of architectural or historical interest are especially likely to give rise to such circumstances. In these situations, the principles contained in the document TGD D may be more relevant and should be considered. While the primary route for establishing the fitness of a material for its intended use is through the recognised standardisation procedures referred to in paragraphs (a), (b) or (c) of Requirement D3 of the Building Regulations, other methods may also be considered in establishing fitness including:

- independent certification schemes of approved bodies, e.g. the National Standards Authority of Ireland (NSAI). Such certification schemes may provide information on the performance of a product or certify that the material complies with the requirements of a recognised document and indicates it is suitable for its intended purpose and use. Accreditation of the body, by a member of the European cooperation for Accreditation (EA) such as the Irish National Accreditation Board (INAB), offers a way of ensuring that such certification can

[52] Dodd et al. (2020)

be relied on. All such certification schemes may be in addition to, but not conflict with, CE marking
- tests and calculations carried out by an accredited laboratory showing that the material is capable of performing the function for which it is intended. Accreditation by a member of the European cooperation for Accreditation (EA) such as the Irish National Accreditation Board (INAB) offers a way of ensuring that tests are conducted in accordance with recognised criteria and can be relied on
- performance in use, i.e. that the material can be shown by experience, such as its use in a substantially similar way in an existing building to be capable of enabling the building to satisfy the relevant functional requirements of the Building Regulations.

Note: Schemes that comply with the relevant recommendations of I.S. EN ISO 9001:2015 are intended to ensure that materials can be expected to be of consistent quality. They are not intended to show that the materials conform to an appropriate technical specification.

The responsibility for compliance rests with the owner, designer and builder who must ensure that materials are fit for the use for which they are intended and for the conditions in which they are to be used. In assessing the fitness for purpose and conditions of use of a material/product, consideration should be given to durability, safety, local climatic conditions (e.g. wind-driven rain and humidity) and other such issues.[53]

3.3.2 Insulations

While thermal conductivity is often the only factor considered when specifying an insulation type for the thermal upgrade of a building, other factors such as the vapour diffusion resistance factor, embodied energy, global warming potential, toxicity and biodegradability should also be considered. For traditional buildings, it is generally recommended that vapour-open insulations be used to minimise the risk of surface and interstitial condensation. Vapour-closed insulations may be suitable in some limited instances, following careful hygrothermal analysis undertaken by an appropriately qualified and experienced modeller, based on actual material properties for the specific construction involved. Due consideration will also need to be given to appropriate ventilation and moisture production control.

Modern petrochemical-based insulations usually have higher associated embodied emissions in their production than either mineral or bio-based insulations in their first-use life. Extruded polystyrene (XPS) and polyurethane rigid foam (PUR)/polyisocyanurate (PIR) have a high vapour diffusion resistance factor, meaning they inhibit moisture from moving through them, which may retard the evaporation of interstitial condensation.

Mineral-based insulations are produced from naturally occurring minerals and are therefore easier to dispose of safely than petrochemical-based insulations. Mineral-based insulations tend to have higher associated embodied emissions than bio-based insulations due to the intense processing required to convert the minerals into insulation materials. They are vapour-permeable, however, which makes them suitable for use in traditional buildings. For instance, calcium silicate boards (mixture of lime and sand) are capillary active, are hygroscopic and have anti-mould properties, making them suitable for high-humidity environments.

[53] This could include buildings located within a similar external climatic environment (rainfall, wind, temperature, relative humidity, etc.) and with similar internal risk profiles (occupancy, relative humidity, temperature, ventilation, etc.)

Bio-based insulation materials are usually vapour-permeable and, where not treated with biocides to prevent them rotting during their use life, tend to have low associated end-of-life emissions as they are naturally occurring and require little processing. Cork or hemp can be mixed with traditional lime renders and plasters to produce an insulating, yet vapour-permeable, natural lime-based finish that is both visually and technically appropriate for traditional buildings. Other bio-based insulations may include, but are not limited to, wood-fibre, hemp-fibre and sheep's wool. Building materials must meet requirements D1 and D3 for proper materials contained in Part D of the Second Schedule to the Building Regulations 1997 to be certifiable as compliant with the requirement of the building regulations.

In TGD L, the acceptable levels of heat loss for each of the plane elements of an existing building are specified in terms of average area-weighted U-value (Um) for material alterations and material changes of use. These values can be relaxed for individual elements or parts of elements where, and to the extent that, they can be shown to be likely to cause long-term damage to the fabric of the building.

3.3.3 Membranes

A variety of membranes exist to moderate or restrict airflow and moisture movement. Certified 'intelligent' airtight membranes, which react to humidity conditions by varying their vapour transfer properties, are able to balance vapour pressure from either side of the membrane under specific conditions of temperature and humidity. These membranes can be helpful in traditional construction to assist with moisture balancing and can enhance seasonal drying processes.

Membranes that are not capable of releasing trapped interstitial moisture can lead to long-term damage to the traditional building fabric and are, therefore, to be avoided.

Membranes should be sealed at perimeters, and where pipes or cables penetrate them, using certified airtightness tapes, mastic beads or grommets.

3.3.4 Renders and Plasters

Lime or earth-based renders were traditionally used to protect solid masonry or earthen walls from driving rain, but they also provide relatively high levels of airtightness. Wet lime-based renders can be finished either as roughcast or trowel-applied and smooth. The latter was sometimes ruled-and-lined for a more refined finish.

In many cases, traditional lime-based renders, plasters and mortars were replaced in recent times with an inappropriate cementitious material that is not vapour-permeable and has the potential to trap moisture within the building fabric. Historic Roman cement and other early cementitious renders may be original to the building, in which case they should generally not be removed. However, in general, inappropriate cementitious material should be removed from traditional buildings where it is possible to do so without damaging the historic building fabric, whether it is in the form of a render, an internal plaster or a cement-based mortar for pointing of stone or brick. Advice from a specialist conservation consultant should be followed to determine potential damage mitigation measures for removal of cement-based materials.

Where sufficient data exists on the material properties of the construction, a building physics approach using hygrothermal analysis to I.S. EN 15026:2007 may be used to assess the moisture transport and balancing capacity of the construction, in which case it may be possible to retain existing cementitious renders, plasters and pointing.

Insulating lime renders and plasters may be suitable for traditional buildings as they are vapour-permeable and can improve the thermal efficiency of solid walls without causing long-term damage to the traditional fabric. However, these need to comply with 'proper materials' as defined in TGD D and the maximum thickness should be subject to confirmation via hygrothermal analysis.

3.3.5 Pointing

In the case of an exposed external brick or stone finish, lime-based pointing materials should be used. The function of the joint is to allow moisture freedom of movement within a vapour-permeable envelope. When this is changed to a cement-based system, it forces the moisture through the stone or brick, which results in physical damage to that material. The pointing should always be softer than, and therefore sacrificial to, the brick or stone. Where cement-based pointing can be removed without causing damage to the surrounding brick or stone, this should be removed and replaced with a permeable lime-based pointing.

3.3.6 Paints

Vapour-permeable paints such as natural emulsion, lime or clay-based paints are advised for use with vapour-permeable constructions. Standard vapour-closed petrochemical-based paints may restrict the natural movement of moisture even if vapour-open insulations and materials have been used beneath them. There are a number of mineral-based and moisture permeable paints on the market, but their vapour resistance factor should be checked to ensure they are sufficiently vapour-open for the application involved.

Figure 24: Example of cement render applied to a traditional building

Figure 25: The same building with drainpipe leak fixed and the cement render replaced with a traditional moisture-permeable lime render. Note the addition of a channel drain, which helps to lower the ground moisture level close to the wall

Mineral-based paints have been in use since at least the nineteenth century, and are typically made of naturally occurring materials, such as chalk, lime, pigment and water. These may be a lower carbon and more environmentally friendly option than petrochemical-based paints. Mineral-based paints also tend to have a lower VOC content than standard petrochemical-based paints, which may be advantageous where buildings are made more airtight.

3.3.7 Cladding

Traditional buildings were often provided with rain-screen cladding where solid walls proved incapable of attaining an acceptable moisture balance for human occupation, to protect sensitive internal finishes or where moisture-sensitive materials were being stored. Coastal buildings and buildings in exposed locations often employed timber shingles, timber boarding, clay tiles or slates, usually hung on timber battens fixed to the external face of the wall or bedded in lime mortar. In many instances, the claddings were provided as a retrofit solution when rendered solid walls failed to provide sufficient weather protection. Such walls provide the highest levels of weather protection found in traditional construction and mirror the performance of modern rain-screen wall construction, yet maintaining good vapour permeability. They are effective against repeated wetting from wind-driven rainfall common in coastal areas and at high altitudes. Often only the most exposed south- or west-facing façade was traditionally over-clad.

3.3.8 Windows, Doors and Rooflights

The first option should always be to retain and, where necessary, refurbish existing historic windows, doors and rooflights. Where original or early replacement windows are still in situ and are in good working order, these should be repaired as necessary to ensure an airtight fit and should be draught-proofed with a discreet

Figure 26: Natural slate hung front elevation

Figure 27: Timber sash window with some original glass panes

draught-proofing system. Slim-profile secondary glazing can provide significant U-value improvements and can be reversible from a conservation perspective.

In cases where it is decided to replace windows and doors, timber is generally a good option in terms of suitability for traditional buildings, thermal efficiency and embodied carbon where timber was the original material used. Where it is considered appropriate to replace existing windows and doors, the design of the replacement windows and doors should be based on archival records, such as drawings or photographs, or appropriate surviving examples in this or other buildings. New windows and doors should be sympathetic with the architectural character of the building in terms of materials, design, scale and proportion while meeting the performance requirements of TGD L, as appropriate.

3.4 Retrofit Measures

3.4.1 Typical Retrofit Measures and Potential Risks

The general compatibility of a series of common retrofit measures for roofs, walls and floors is provided in Table 9. The compatibility rating is based on their general impact on historic building fabric and the associated level of risk they pose in terms of thermal bridging, condensation and ventilation. The compatibility rating ranges from low (green) to high (red), but ultimately it is for the building professional to decide when expert advice or additional surveys and modelling are required to confirm that any proposed retrofit measures would do no long-term damage to the building fabric or harm to the occupants.

Table 9 is designed to act as a general guide to the compatibility and associated risks of common retrofit works for traditional buildings, but as the context, condition and construction of each building can differ, it is essential that building professionals carry out their own risk assessment at the outset of a retrofit project. These tables should be regarded as a support to the exercise of professional judgement in decision-making and should not be regarded as prescriptive for the specification of any works. The responsibility for the design of the works therefore remains entirely with the certified specifier.

For any measures exhibiting a yellow to red compatibility rating, the advice of a competent building professional such as an architect or building surveyor with conservation experience/ accreditation should be followed (see Table 3 and 4). They should be able to identify the significant character of the building and design a suitable retrofit strategy in line with findings from any additional surveys and/or hygrothermal risk assessments.

Table 8: Key to the general compatibility of retrofit measures in terms of impact to historic building fabric and hygrothermal risks

Compatability Rating	
(dark green)	Compatible.
(light green)	Generally compatible with traditional buildings. Presents some impact to historic fabric and some long-term risk to building fabric, which can be managed with expert advice.
(yellow)	Conditionally compatible with traditional buildings where adequate mitigation measures are put in place under the direction of an expert.
(orange)	Generally not compatible with traditional buildings. Presents significant risk of impact to historic character and/or long-term risk to building fabric. Expert professional advice will be required to fully assess these risks and specify the significant mitigation required.
(red)	Not compatible.

Hygrothermal risk assessments are recommended for any measures with yellow compatibility ratings and highly recommended for orange or red compatibility ratings. For traditional construction, condensation risk assessments should be carried out in accordance with I.S. EN 15026:2007 and thermal bridge modelling[54] in accordance with I.S. EN ISO 10211:2017 and BR497 using proprietary software programmes. These assessments should be done at an early design phase so that specifiers can evaluate the risk and alter materials and their application specifications as required.

Further guidance on the retrofit of each building element is provided in Section 3.4 below.

[54] NSAI maintains a register of qualified thermal bridge modellers on its website

Table 9: General compatibility of typical retrofit measures with a traditional building, where not otherwise precluded by virtue of its statutory protection. This table is for guidance only. Each building will require assessment on a case-by-case basis

Features	Measures	Compatibility				
Outer walls	Repair/renewal to traditional masonry, pointing, render, etc.	dark green				
	IWI on walls without historic features (if not a protected structure)				orange	
	IWI on walls with historic features					red
	EWI on walls without historic features (if not a protected structure or in an ACA)				orange	
	EWI on walls with historic features					red
Ground floor	Draught proofing between or below floorboards		light green			
	Insulation between suspended timber floors			yellow		
	Insulation below solid masonry floor			yellow		
	Insulation above solid masonry floors				orange	
Roof	Rafter-level insulation			yellow		
	Attic-level insulation		light green			
Windows	Replacement of traditional windows (to be determined on a case-by-case basis)				orange	
	Optimisation of traditional windows (e.g. repair, draught proofing)	dark green				
	Installation of double glazing				orange	
	Installation of secondary glazing		light green			
	Installation of insulating panel(s) to shutters		light green			
Doors	Replacement of traditional doors (to be determined on a case-by-case basis)				orange	
	Optimisation of traditional doors (e.g. repair, draught proofing)	dark green				
	Installation of insulating internal panels		light green			
	Renovation of door construction (to address warping etc.)			yellow		
Heat & energy systems	Optimisation of existing systems (cleaning, repair, etc.)	dark green				
	Wholesale replacement of existing systems		light green			
	Wholesale replacement of existing systems in protected structures				orange	
Ventilation	Optimisation of existing systems (cleaning, repair, etc.)	dark green				
	Installation of mechanical ventilation systems		light green			
	Installation of mechanical ventilation systems in protected structures				orange	
Solar photovoltaic (PV) & solar thermal	Installation to outbuildings and open spaces		light green			
	Installation to traditional building that is not a protected structure			yellow		
	Installation to traditional building within an ACA			yellow		
	Installation to a protected structure				orange	

Notes on Table 9:

The compatibility ratings presented in this table are for guidance only. It is up to the building designer/specifier to assess the compatibility and associated risk for each building as they will differ from one building to the next. It can be assumed that the risk will be reduced if the recommendations provided within this guidance document are followed and/or if advice from the recommended specialists is followed.

All insulations and draught-proofing materials must support the long-term health of the building fabric, especially in terms of moisture management. All products must be proper materials as defined in TGD D and installed/applied in accordance with the manufacturer's specifications.

In protected structures and buildings in ACAs, only thermal or energy-efficiency upgrades that are compatible with the character and special interest of the building or area should be considered. In such cases, the local architectural conservation officer should be consulted at the outset of the project.

Where a property is a protected structure, a proposed protected structure, or is located within an ACA, the appropriateness or otherwise of any proposed retrofit measure will be determined by the local authority.

Further information on risk assessment is available from the Sustainable Traditional Building Alliance in its *Responsible Retrofit Guidance Wheel*.[55]

[55] Sustainable Traditional Building Alliance (2017)

3.4.2 Roofs

Insulating a pitched roof is generally one of the most effective and least intrusive measures to improve the energy efficiency of a traditional building, where correctly carried out. An estimated 25% of heat is typically lost through a building's roof. Where problems exist with the roof, the consequences of water ingress can extend throughout the rest of the building. This means that by starting with improving and adding insulation to the roof, the general condition and energy performance of the entire building is improved.

Pitched roofs can be insulated at either ceiling level or rafter level. Before embarking on insulation works, decisions will need to be made based on the existing condition and build-up of the roof, ventilation provisions and restrictions, and how the attic space is intended to be used. These considerations will determine which insulation method should be pursued. Insulation should be fitted tight to the existing ceiling to avoid creating a cavity on the warm side of the insulation that might attract interstitial condensation.

Flat roofs are generally of modern construction and therefore any retrofit works to these should comply with Building Regulations and follow the guidelines and minimum efficiency standards set in TGD L. Further guidance can be found in S.R. 54:2014&A1:2019 – *Code Of Practice for the Energy-Efficient Retrofit of Dwellings*. However, historic flat roofs were often used over parts of large buildings such as country houses or churches. These were usually clad in lead, copper or zinc. Where these are found, it is important to ventilate the underside of metal-sheeted roofs as, if condensation is allowed to form on the underside of lead, it will oxidise, rapidly forming a toxic lead-oxide powder. If oxidation continues unchecked, holes will form in the lead, allowing the roof to leak. As internal access to the structure of flat roofs is often difficult, they are best upgraded when undertaking repair works to replace the roof finish above or the ceiling finish below.

Ventilation is very important for roofs. With poor ventilation, moisture can enter the roof from the rest of the building and if the roof is unventilated, interstitial condensation can occur, increasing the risk of mould growth. Diagram 11, TGD F demonstrates the minimum ventilation void required in different roof build-ups to maintain a healthy internal environment and to manage condensation risks.

The technical guidance provided in S.R. 54:2014&A1:2019 in relation to the energy upgrading of pitched roofs may be applied to traditionally constructed timber roofs with an existing slate or tile weathering layer.

In buildings where a section of the ceiling is sloped in line with the roof pitch (sometimes referred to as a 'coombe'), a hybrid approach using both ceiling-level insulation between and above the collar ties and rafter-level insulation behind the sloped section may be used.

Insulating roofs with a ceiling in line with the rafters presents more risks, so it is recommended to undertake hygrothermal and thermal bridge risk assessments to ensure that the proposed insulation materials and installation methods will not lead to unintended consequences.

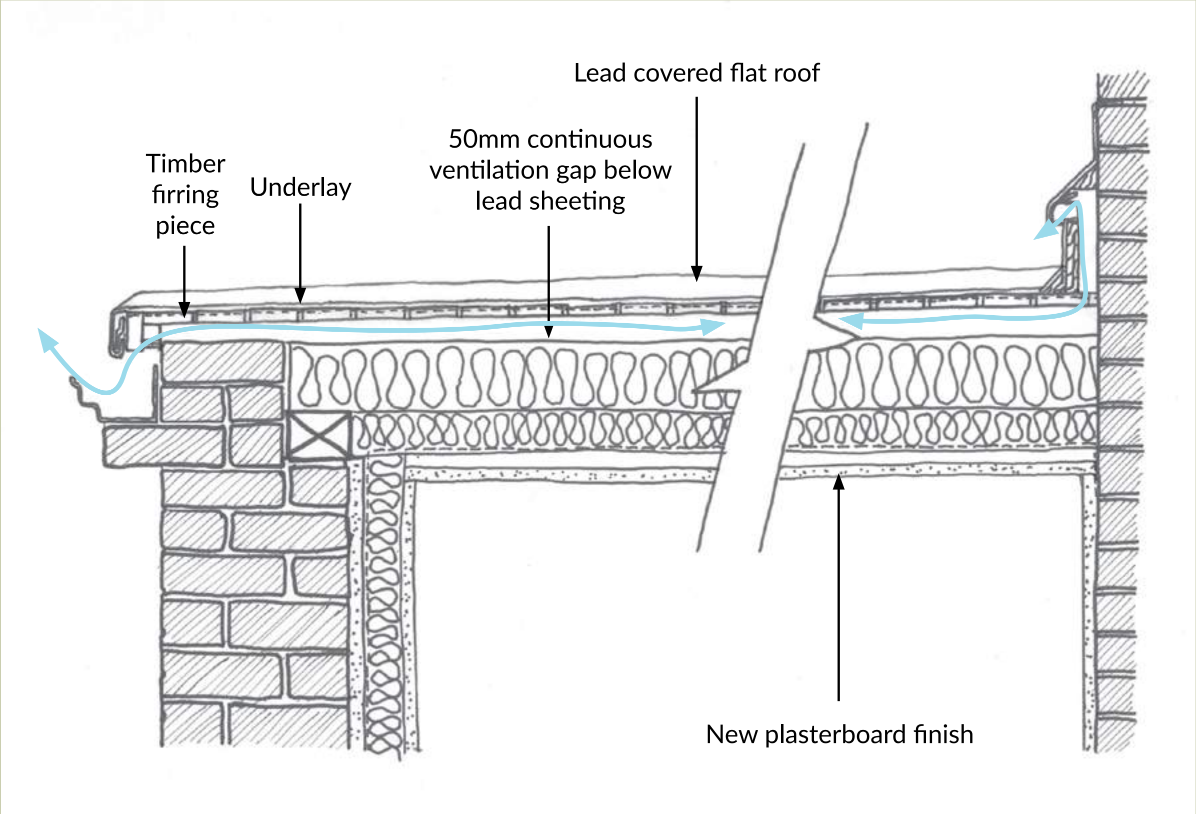


Figure 28: A section through a typical traditional flat roof showing how it might be thermally upgraded

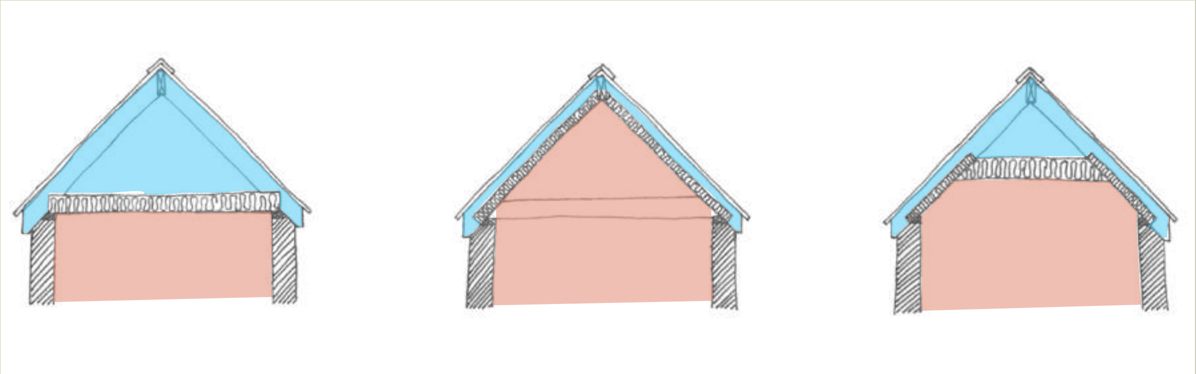
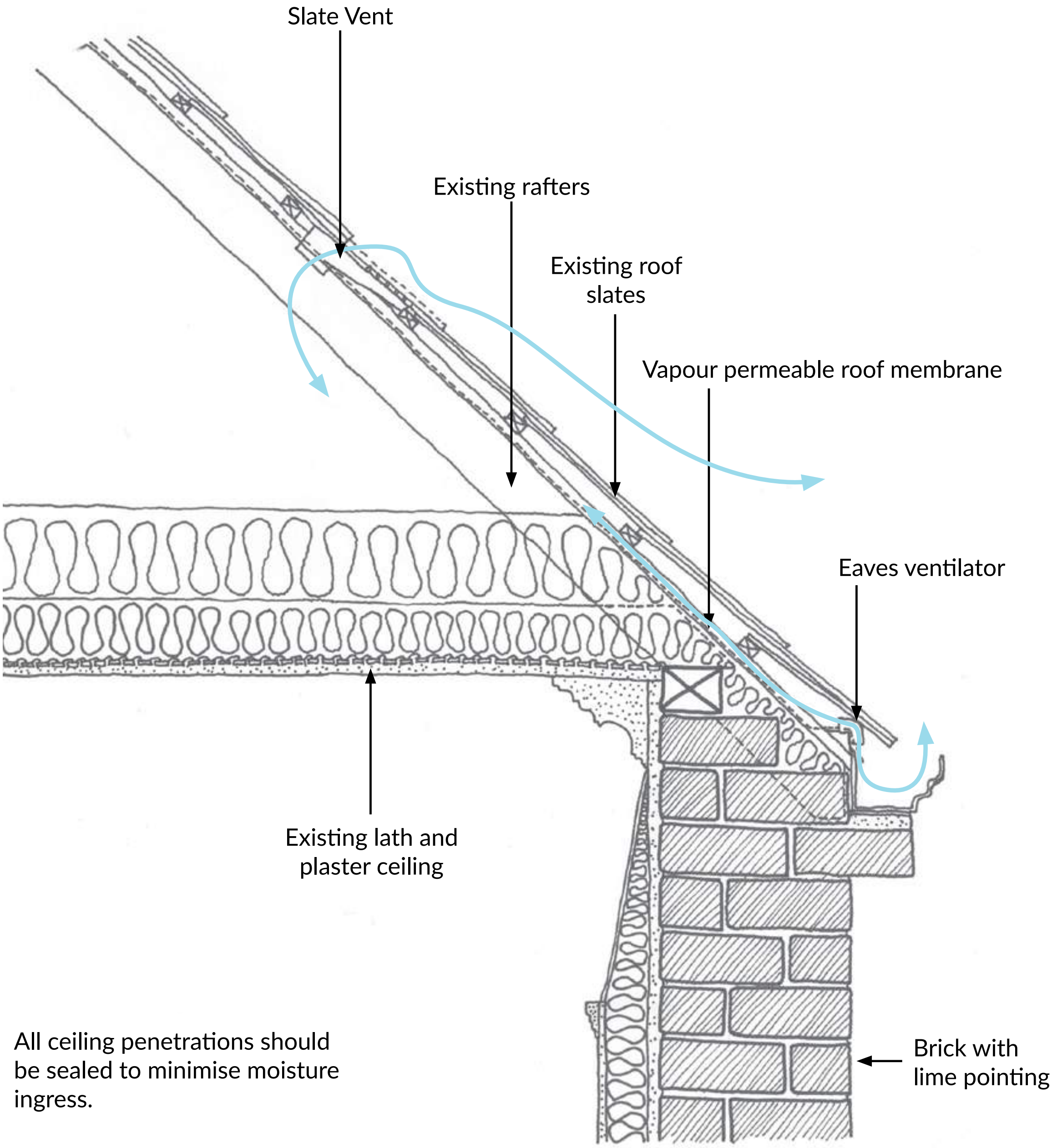


Figure 29: Pitched roofs can be insulated either at ceiling level, or rafter level, or a combination of both. The cold area of the attic (blue) must be adequately ventilated at all times

3.4.2.1 Pitched Roofs – Insulating at Ceiling Level

Pitched Roofs: General Preparation
Check for wildlife, such as bats.
Clear loft of stored items and any redundant cables, pipes and plumbing.
Cabling that must remain should be raised above insulation where possible or run in conduit to prevent overheating beneath insulation.
Any source of water ingress in roof space should be identified and repaired.
Any other necessary repairs should be carried out to the roof before insulation is installed.
Assess whether any existing insulation can be reused or if it should be replaced. Remove any damp or inappropriate insulation.

Pitched Roofs: Installation – insulation at ceiling level
Ensuring that there are no gaps, the first layer of insulation should be laid between and to the full width and depth of the joists, right up to adjacent walls where possible. Building paper should be installed between the insulation and any damp walls.
A second layer of insulation should be laid perpendicularly across joists to cover any thermal bridges. Care must be taken to fit the insulation neatly around any trusses that are in the way to avoid gaps.
Insulation should extend as far as possible over the wall plate while leaving a minimum 25mm continuous gap at the eaves for airflow. An eaves ventilation tray or battens can be used to keep the insulation out of the airflow zone.
Airflow in an insulated roof is extremely important, as without adequate ventilation moisture can build up and lead to damage and decay of roof timbers.
Insulated walkway boards can be installed over insulation for access. Boards must be diffusion-open to allow any trapped moisture to escape.
Where possible, attic hatches should be insulated to the same level as the rest of the loft. Vapour control membranes should be sealed around the perimeter of the hatch with airtightness tapes. Compressible draught-proof stripping must be installed at the perimeter of the attic hatch to prevent warm moist air from inside the thermal envelope escaping into the attic and condensing on cold attic timbers. Insulated airtight attic hatches can also be purchased as a single unit.
Install recessed lighting with a fireproof hood and lay insulation over top. The replacement of existing light fitting with LED light fittings can achieve significantly lower operating temperatures.
Pipework, water tanks or ductwork should be fully insulated/lagged to avoid freezing and reduce heat loss during winter months (see TGD G). Alternatively, these services may be relocated within the heated building, if possible.
Measures should be taken to limit transfer of water vapour to the cold attic. Care should be taken to seal around all penetrations of pipes, ducts, wiring, etc. through the ceiling, including the provision of an effective seal to the attic access hatch. The combination of vapour-permeable insulation, well-ventilated attic spaces and sealed penetrations removes the need to install vapour-control membranes in most roofs.
Where the roof pitch is less than 15 degrees, or where the shape of the roof is such that there is difficulty in ensuring adequate ventilation, e.g. dormers or bay windows, an effective vapour control membrane on the warm side of the insulation may be required to assist in limiting vapour transfer but cannot be relied on as an alternative to ventilation.



All ceiling penetrations should be sealed to minimise moisture ingress.

The second layer of insulation should be laid perpendicular to the first to cover any gaps. If an access walkway is required, it should be laid between supports running perpendicular to the ceiling joists to minimise thermal bridging

Figure 30: Recommended insulation measures at ceiling level

3.4.2.2 Pitched Roofs - Insulating at Rafter Level

Alternatively, the roof can be insulated at rafter level in line with the pitch of the roof.

Pitched Roofs: Preparation
Access to the rafters will need to be gained either from inside or from outside the roof, but never from both, as destruction of historic fabric should be minimised.
If internal finishes are historically valuable, existing slates/tiles will need to be carefully removed and should be stacked for reuse (if still within useable life). The condition of the rafter ends and wall plate should be inspected at this time.
Necessary repairs to the roof should be made prior to the installation of insulation.
Compliance with TGD F must be achieved with any roof insulation upgrade. Any roof design should be checked in accordance with S.R.54, I.S. EN ISO 13788:2012 and/or I.S. EN 15026:2007 as appropriate to ensure no risk of interstitial condensation exists.
As with ceiling-level insulation, care must be taken with any electrical cables, which should be relocated if possible or placed within conduit to avoid overheating when run within an insulation layer.
If dormers exist, early consideration should be given to how the dormer roofs and cheeks will be insulated.

Pitched Roofs: Installation – insulation between and above the rafters
Insulating at rafter level works best when the external roofing materials (slates, tiles, etc.) are due for replacement. This allows for the addition of full-fill insulation between rafters as well as insulating sarking boards (e.g. wood-fibre) and a breather membrane above the rafters, thus reducing the risk of thermal bridging through the rafters. This build-up will raise the roof level by 50–100mm including provision of counter-battening, which may not be appropriate for protected structures, buildings in ACAs or terraced and semi-detached buildings.
A system of battens and counter-battens should be installed to the outer face of the rafters to provide the necessary structure to affix the slates/tiles to and to provide adequate space for ventilation between the wind-tight breather membrane and the slates/tiles. Ventilation inlets/outlets should be provided at the eaves and ridge.
Insulation should be installed to fill the full depth and width of the rafters. Where necessary, compressible insulating tapes can be used to seal any gaps between the insulation and rafters. A vapour control membrane, which may also act as an airtight membrane, should be laid between the insulation and new ceiling finishes. Refer to Section B.5.2.2 and Diagram B4 of TGD L for installation guidelines and precautions. Ideally an intelligent vapour-control layer (VCL) will be used which permits drying to inside as well as vapour control.
Due to the lower thermal performance of vapour-permeable, natural insulation products, greater thicknesses may be required to ensure that the minimum temperature factor is achieved (refer to TGD Appendix D for details).

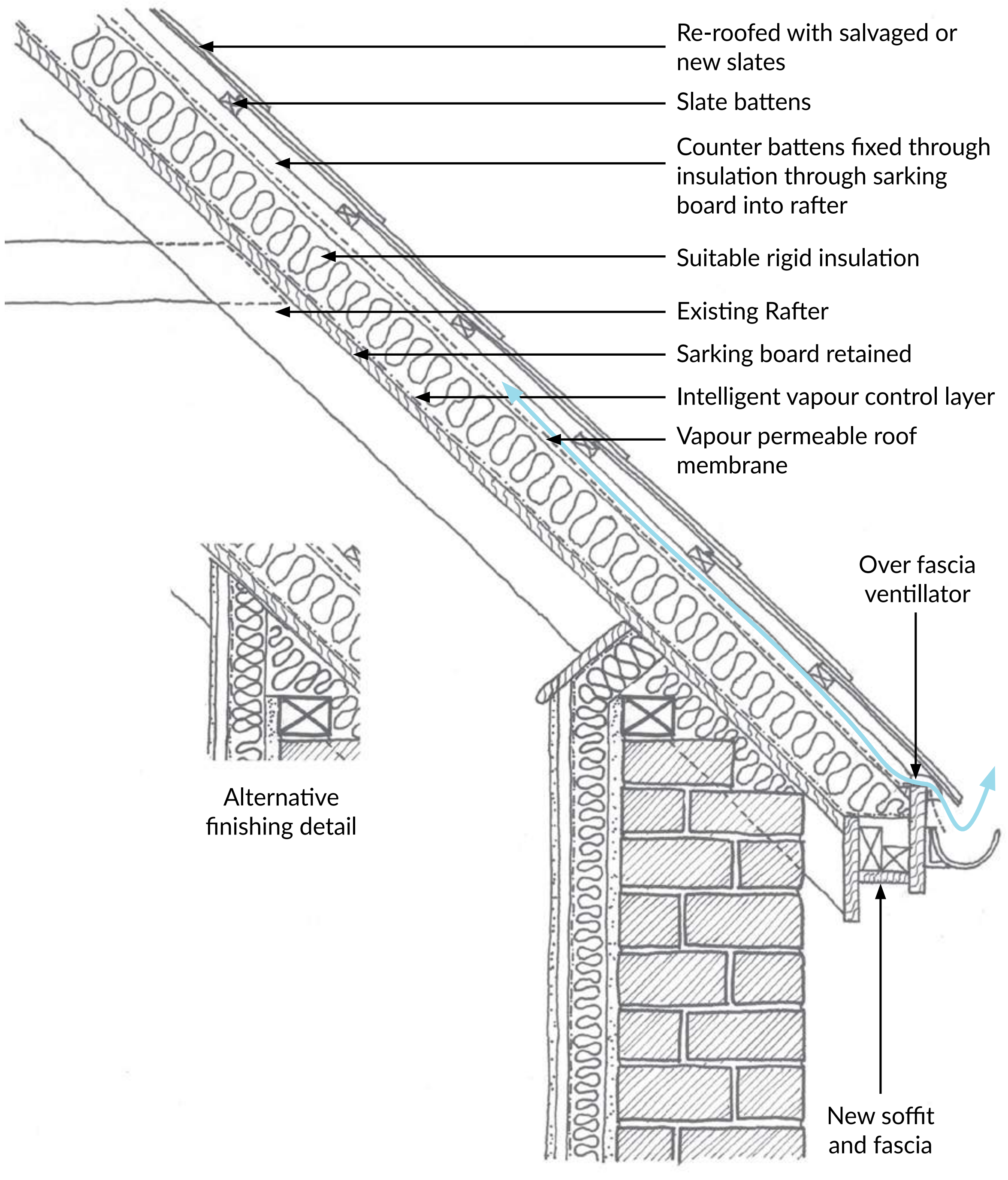


Figure 31: Insulation above and between rafters. An insulating board to the external face of the rafters reduces the chance of thermal bridging but will raise the roof level and may not be acceptable in certain cases

Pitched Roofs: Installation – insulation between and beneath the rafters

It is important to maintain adequate ventilation levels to allow for the removal of excess moisture. Ventilation inlets/outlets should be provided at the eaves and ridge. TGD F Diagram 11 demonstrates the minimum ventilation gaps required for different roof build-ups.

If the rafters are open internally or the existing plaster is to be removed, insulation should be installed as described above with the exception that a 50mm well-ventilated air space should be maintained to the cold side of the insulation. To achieve this well-ventilated air space, battens can be fixed to the rafters prior to the installation of insulation. Refer to Section B.5.2.1 and Diagram B3 of TGD L for installation guidelines and precautions.

Vapour-permeable semi-rigid insulation should then be installed to fit tightly between the rafters. A vapour control membrane, which may also act as an airtightness membrane, should be fitted on the warm side of the insulation to limit moisture accessing the insulation layer; see Appendix B.4 of TGD L. Ideally an intelligent VCL will be used that permits drying to inside as well as vapour control.[56]

Any ceiling finish fitted below the VCL should be installed so as not to puncture the VCL. This can be done by fixing the ceiling to a counter-batten fixed through the insulation to the underside of the rafter, with a layer of mastic on the upper face of the counter-batten to ensure an airtight seal.

Due to the lower thermal performance of vapour-permeable natural insulation products, greater thicknesses may be required to ensure that the minimum temperature factor is achieved (refer to Appendix D of TGD for details).

3.4.2.3 Dormers

Where dormer windows exist, the dormer cheeks and roof will need to be insulated to the same level as the rest of the roof (if possible) to minimise heat loss through these areas. If the roofing is being replaced, it may be feasible to remove the roof and cheek claddings from the dormer(s) in order to install insulation from the outside, complete with insulating sarking boards, a wind-tight breather membrane and a batten and counter-batten system. This, however, will widen the cheeks and raise the roof level, which may not be visually acceptable for historic buildings. The dormer cheeks will also need to be ventilated if they are covered with a vapour-closed material such as lead.

If external roofing and cladding cannot be removed, it may be acceptable to remove internal finishes, bearing in mind the architectural character of the building.[57] As with the internal access rafter insulation (above), it is recommended to commission thermal bridge modelling if the dormer roof and cheeks are only to be insulated between the rafters and cheek studs.

In no case is it acceptable to produce a roof insulation solution that fails to achieve the critical surface temperature required to avoid surface condensation and mould growth as described in Appendix D of TGD L. Careful selection of vapour-open, high-performance insulation may be required to achieve the critical surface temperature.

Interstitial condensation risk is high in dormer construction and it is also recommended to undertake a hygrothermal risk analysis. Where the shape of the roof is such that there is difficulty in ensuring adequate ventilation, an effective VCL on

[56] An airtight membrane on its own may not be sufficient to prevent interstitial condensation forming in the insulation layer because an airtight layer controls air flow but not necessarily moisture transfer. In contrast, a VCL's primary function is to control the amount of moisture vapour entering the roof. Without it, interstitial condensation could form in the middle of the insulation layer, wet the rafters and potentially cause wood rot. Ideally an intelligent VCL will be used, which provides for drying to the inside as well as vapour control

[57] For more detailed analysis of dormer insulation, see Pickles (2016)

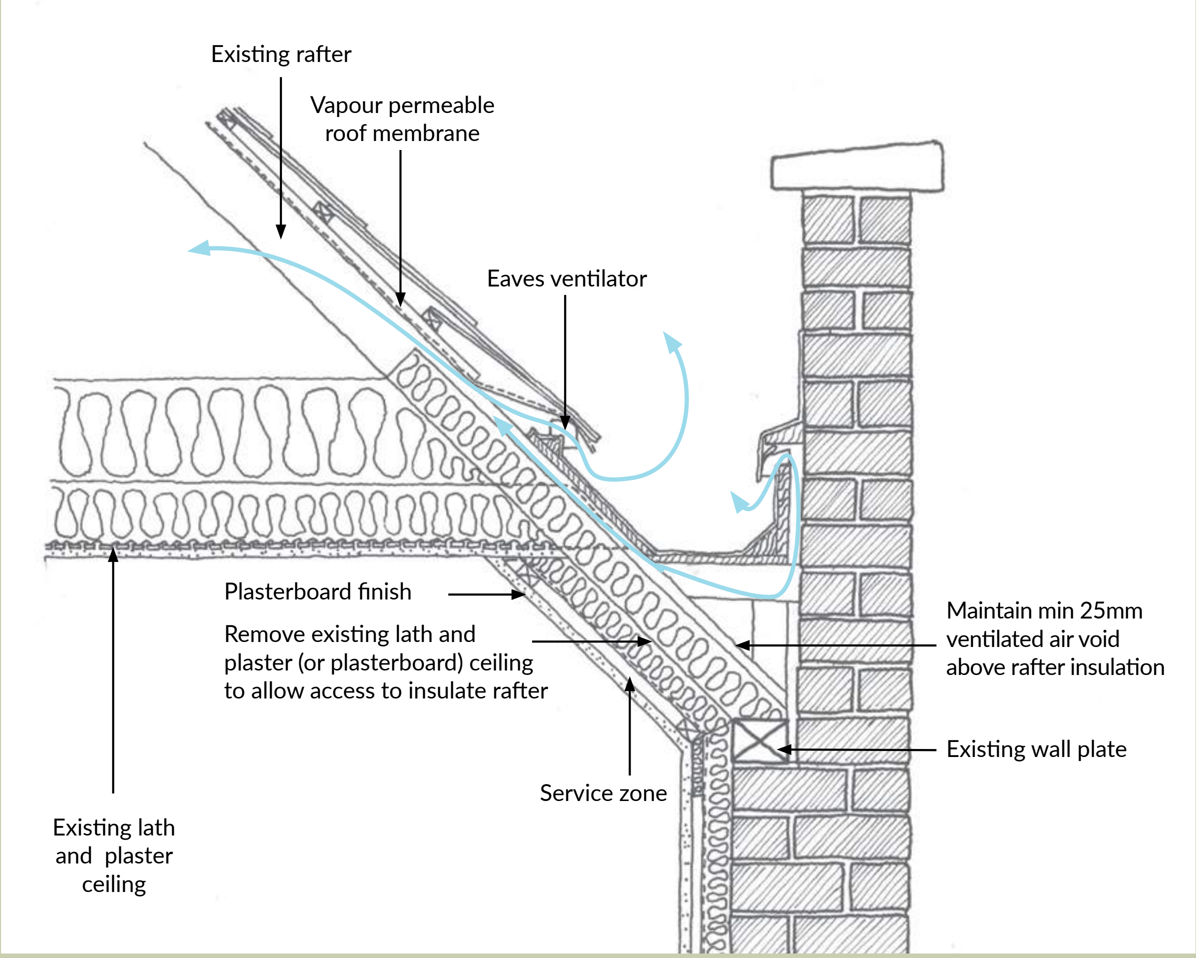


Figure 32 : A hybrid system combining horizontal insulation at ceiling level and pitched insulation at rafter level to the sloped section of ceiling can also be used

Figure 33: Wood-fibre insulating sarking board being applied between the rafters at roof level. (Image courtesy of OPW)

Figure 34: Wood-fibre insulation board fixed to the internal face of rafters. Thermal modelling may be required to ensure the minimum surface temperature is achieved in accordance with TGD L, Appendix D

the warm side of the insulation may be required to assist in limiting vapour transfer but cannot be relied on as an alternative to ventilation. Ideally an intelligent VCL will be used which permits drying to inside as well as providing vapour control.

Full checks should be performed on the likelihood of surface and interstitial condensation of the dormer construction detail in accordance with I.S. EN ISO 13788:2012. This standard contains recommended procedures for the assessment of the risk of:

- surface condensation and mould growth
- interstitial condensation.

The guidance in BRE document *BR 497 Conventions for calculating linear thermal transmittance and temperature factors*[58] may be used to perform the checks in I.S. EN ISO 13788:2012. I.S. EN 15026:2007 can also be used to assess the risk of surface and interstitial condensation and mould growth.

3.4.2.4 Chimneys

Chimneys were traditionally an important part of the heating and ventilation systems of buildings. As comfort standards and the availability of coal increased in the eighteenth and nineteenth centuries, it became common for most rooms in houses to contain an open fireplace proportional to the size of the room. The chimneys therefore became more complex, integrating flues from multiple fireplaces. In addition to providing a heat source, chimneys ventilate buildings by drawing new air into the room in the form of draughts.

Heating a building with open fires is not an efficient method, and these are becoming redundant as a heat source. Without the drying effect of the fire, chimneys are vulnerable to becoming saturated and a source of mould spores and plant growth. Where retained, they should be appropriately pointed and capping repairs carried out using lime render and augmented with the use of a rain-shedding cowl and enhanced capping. The excess airflow required by the chimney should be controlled as much as possible through the use of dampers, chimney caps or other flue restrictors.

Fireplaces and chimneys can have historic and architectural value, and changes will likely require planning permission if the building is a protected structure or is contributing to the character of an ACA.

Repairing Chimneys
If a chimney has been unused for some time, it is recommended to carry out a visual inspection, using a camera to see hard-to-reach areas. Leakage points in the chimney can be identified using a smoke test.
Vegetation growth is an indicator of a serious failure of a chimney. All such vegetation should be removed and, where necessary, masonry treated with biocide to prevent regrowth.
Any necessary repair works on the chimney should be carried out, ensuring pointing, capping and flashing are in a state of good repair and provide an effective barrier against moisture ingress and that the individual flues are fitted with rain-shedding cowls or terminals.
When carrying out work on a chimney, ensure that any replacement work matches the original in colour, texture and compressive strength. If the coping is being replaced it should be done in appropriate materials with the correct drip detailing on the underside to ensure water is shed clear of the chimney stack. Where buildings have a string course or band of projecting masonry that throws water clear of the chimney, this should be retained or reinstated.

[58] Ward et al (2016)

Repairing Chimneys continued

Cement mortar is generally not appropriate for brick or stone chimneys and should be removed and replaced with a lime-based mortar.

Check for debris in a used or disused chimney by having it swept. Even a disused chimney needs to be maintained and kept free of debris to help prevent the accumulation of condensation and moisture build-up.

Proprietary chimney caps should be installed to redundant flues to prevent birds nesting, rainwater ingress and debris falling into the chimney.

Where chimney flues are being considered for ventilation, the flue and chimney should be checked and, if necessary, altered to ensure that they satisfy the requirements for ventilation. Any ducting installed must be in accordance with TGD B, TGD F and TGD L.

If a chimney, flue or heat-producing appliance is to be renovated for re-use, or is being replaced, all associated works, including the provision of adequate ventilation, are required to comply with the requirements of Part J and the provisions of TGD J.

Reducing Draughts in Unused Chimneys

If chimneys are closed off permanently, the ventilation requirements of the building will have to be met by other ventilation provision as described in TGD F.

Flue balloons, dampers or register plates with ventilation holes can be used to reduce excessive air leakage and draughts in unused chimneys without closing off the chimney permanently. Cast-iron fireplaces often had built-in dampers, which could be closed while the fireplace was not in use. These can be repaired or reinstated if lost. Redundant flue runs, if they require to be ventilated, should be vented at fireplace level and at chimney pot level only, to avoid breaching fire compartmentation.

Using Chimneys for Ventilation

With suitable airflow controls, chimneys can continue to be used as ventilation shafts within designed ventilation systems. Where a chimney is to remain as part of the natural ventilation strategy for the building, the existing chimney liner must be thoroughly inspected and cleaned.

Where a fireplace is being retained as an open fire space, adequate permanent ventilation must be provided to the room containing the fireplace (i.e. 550mm2 per kW of rate output and no less than 6500mm^2 where air permeability is less than 5.0m3/h.m2) in accordance with TGD J.

It may be possible to use a disused chimney for extract ventilation. Air ducts must run the full length of the flue and be sealed at the point of discharge to avoid condensation issues within the chimney. Ducts may need to be insulated where they pass through the thermal envelope.

With regard to insulation specification of services/ductwork, guidance provided in TGD F and TGD L should be followed in order to reduce heat losses from ducting and services, as well as to eliminate risk of condensation forming in ducting and on fittings.

In the case that the decommissioned chimney will continue to be used for ventilation purposes, it is no longer a flue, it is a service duct and all necessary considerations in TGD F and L should be followed e.g. the measures discussed below under 'Insulating Unused Chimneys' should be followed.

Insulating Unused Chimneys

If the chimney is external to the façade line and permanently closed, this will allow an IWI system to be installed across the internal wall face. Where an EWI is applied to an external chimney breast, consideration will need to be given to extending the flashing or capping at the top of the chimney to prevent water ingress behind the EWI system. Consideration should also be given to ensuring continuity of insulation at abutments with other building elements, such as roofs insulated at ceiling level, to avoid thermal bridging.

If the chimney is internal to the façade line and permanently closed, the IWI system can be made continuous around the internal chimney breast. Consideration should be given to the potential complexity of achieving insulation and, where applicable, insulation continuity across intermediate floors. Where a building is subdivided, or will be subdivided, consideration must also be given to compliance with the requirements of Part B and the provisions of TGD B and other applicable regulations.

Where an EWI system is being applied to an internal chimney breast, the chimney breast at roof level will be flush with the gable wall in many cases and encroach on the roof. Insulation continuity is required around the entirety of the chimney breast, which may require re-flashing of the chimney to account for the increase in thickness. Where the chimney breast runs through a cold ventilated attic space, insulation continuity must also be achieved on the chimney within the roof space, in order to connect, or sufficiently overlap, the insulation at ceiling level with that on the outside of the chimney.

Thermal Bridging due to Chimneys

Where chimneys pass through the thermal envelope, they can cause low surface temperatures at the rafter level and local surface condensation and/or interstitial condensation. It may be necessary to engage a thermal modeller to ensure that the minimum surface temperature is achieved and the risk of surface (or interstitial) condensation avoided. An increase in local surface condensation and/or interstitial condensation could constitute a new or greater contravention of the building regulations.

Figure 35: Traditional chimney stack requiring repair and maintenance

Figure 36: This modern double-glazed skylight allows access to a concealed valley gutter for maintenance inspections and cannot be seen from ground level (Image from *Advice Series: Roofs*, 2010)

Figure 37: Historic skylights and lanterns, such as this fine example, should be well maintained but can be difficult to upgrade thermally. Consideration should be given to adding secondary glazing at ceiling level (Image from *Advice Series: Energy Efficiency in Traditional Buildings*, 2010)

Bats and Historic Roofs

Bats frequently roost in roof spaces and other parts of buildings. They may be found under the slates, hanging from roofing felt, parging or timbers, and in joints and splits in roof timbers. Bats do not pose any significant threat to the fabric of a building or to the health of its human occupants. They are usually only present in the roof space for part of the year but, as they tend to return to the same roosts every year, the roosts are protected whether bats are present or not.

Bats and their roosts are protected by Irish and EU legislation. The Wildlife Acts make it an offence to wilfully damage or destroy the breeding or resting place of a bat. Even where planning permission has been granted or works to a roof are considered exempted development, the requirements of the Wildlife Acts still apply. All bat species found in Ireland are also listed under Annex IV of the EC (Birds and Natural Habitats) Regulations and, as a result, works that would capture or kill them, damage or destroy their roosts or disturb them at important parts of their life cycle cannot take place without first obtaining a derogation licence. This licence is issued under Regulation 54 of the Regulations and strict criteria must be met before it can be approved. Detailed guidance on the protection, how to ensure no offence is committed during building works and the steps involved in the derogation protection is provided here:
https://www.npws.ie/licensesandconsents/disturbance/application-for-derogation-licence

When considering any works to a historic roof, the first step is to have a bat survey carried out by an appropriately qualified bat expert. Where bats are present or there is evidence that they have used or are using a roof, the published guidance should be consulted before any roofing works are programmed and initiated. If there is an active bat roost, works will need to be programmed to avoid disturbance, and measures put in place to allow bats to continue to use the roof space upon completion.

The most common and effective method of minimising the impact of roof repair works on bats is to carry out the work at an appropriate time of the year. The great majority of roosts in buildings are used only seasonally, so there is usually some period when bats are not present. Maternity sites, which are the ones most often found in roof spaces, are generally occupied between May and September, depending on the weather and geographical area, and where bats are present, works should therefore be timed to avoid the summer months.

Larger re-roofing projects, however, may need to continue through the summer. The best solution in such cases is to complete and secure the part of the roof that is the main roosting area before the bats return to breed. If this is not possible, work should be sufficiently advanced by May or June for returning bats to be dissuaded from breeding in that site for that year. In this case, alternative roosts appropriate to the species should be provided in a nearby location. Another possible solution is to divide the roof with a temporary barrier and work on one section at a time so that the bats always have some undisturbed and secure areas. The advice of a bat expert should always be sought, and there may be a requirement for this expert to be present on site during the course of the works.

Where it is proposed to treat roof timbers against fungal or insect attack, careful consideration must be given to ensure that the treatment used will not adversely affect the bats.

Where roofing membranes are to be included as part of re-roofing works, they should be of a type that allows bats to hang from almost any point. Plastic membranes are mostly unsuitable because bats have difficulty hanging on these, so wind-break netting stretched beneath the membrane should be used.

The completed roof should be accessible and amenable to the returning bats. Access to the roof space can be provided in a variety of ways, including the use of purpose-built bat entrances. Bats also need suitable roosting sites and an appropriate temperature regime. This can be provided by the construction of a bat-box within the roof space that has the advantage also of providing some segregation between the bats and the building's occupants.

For further detailed information, see the National Parks and Wildlife Service publication Bat Mitigation Guidelines for Ireland v2 (2022), which can be downloaded here: https://www.eurobats.org/sites/default/files/documents/publications/publication_series/EUROBATS_PublSer_No4_English_3rd_edition.pdf

Additional guidance on how best to manage and protect bats in historic buildings has been published by Eurobats: https://www.eurobats.org/sites/default/files/documents/publications/publication_series/EUROBATS_PublSer_No4_English_3rd_edition.pdf

In addition, guidance is available from Bat Conservation Ireland: https://www.batconservationireland.org/wp-content/uploads/2022/11/BatsHeritageStructures_Final.pdf

3.4.3 Floors

Traditional buildings in Ireland were typically constructed with either a suspended timber or a solid ground floor commonly built of packed rubble and earth, tiles, bricks, flagstones, terrazzo or concrete. It is relatively easy and thermally beneficial to insulate a suspended timber ground floor, but it can be technically difficult, expensive and disruptive to insulate a traditional solid ground floor.

3.4.3.1 Suspended Timber Floors

Suspended timber ground floors can be insulated from above or below, depending on access. Insulating suspended floors from below is often the least disruptive way of installing insulation between the floor joists as it does not require the careful removal and reinstatement of existing floorboards. However, access can be an issue and consideration must also be given to working conditions and the implications for those carrying out works in confined spaces. If the solum (the subfloor area under the floor joists) is less than 600mm in height, it may be better to insulate the floors from above. Maintaining solum ventilation after insulation is very important to remove excess moisture and ground gases such as radon. The recommendations in TGD C should be followed.

Careful investigation of the historic floor should be carried out in advance of an attempt to lift floorboards. Brad nails used in traditional buildings often pull through the floorboard and remain permanently embedded in the joists. These cannot be removed without causing excessive damage to the joist or to the ceilings below, and may instead have to be broken off at surface level and ground down flush. In other cases, floorboards may be connected to each other along their length using dowels, tongues or metal strips and can be damaged during lifting. Floorboards may be brittle and difficult to lift without damage. Their successful lifting is often a job requiring specialist skills and care.

3.4.3.2 Solid Ground Floors

Traditional solid ground floors tend to be difficult to insulate and it may be more appropriate to consider options that avoid this. Fortunately,

Figure 38: Care must be taken when lifting existing floorboards to conserve historic detailing like this biscuit joint

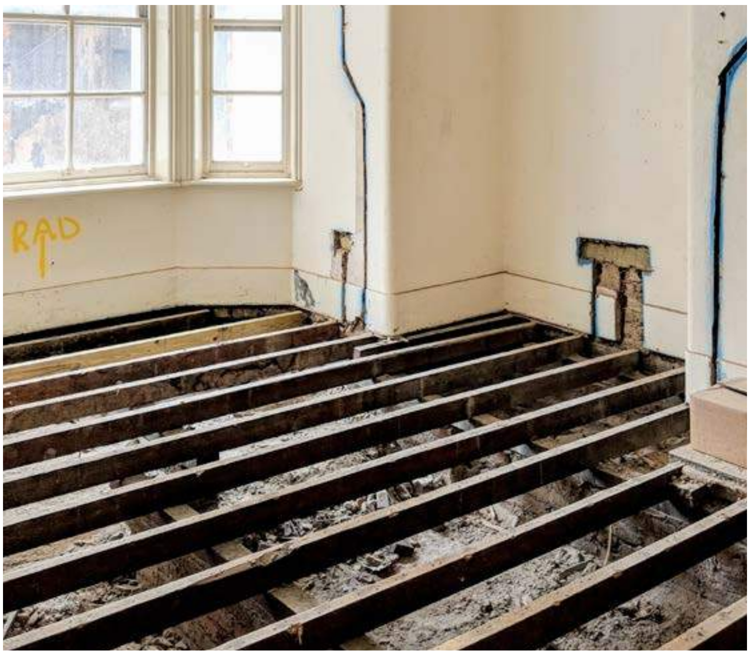


Figure 39: Existing ground floor joists exposed and readied for insulation. The solum should be left free of debris

Suspended Timber Floors: Preparation

If insulating from below, access will need to be gained to the solum area, which should be cleared of debris. Joists and wall plates should be checked for rot and repaired where necessary.

If insulating from above, furniture, floor finishes and certain fixings such as kitchen or bathroom units will have to be removed. Care must be taken not to damage floorboards if they are to be reinstated.

If the building is a protected structure, the floorboards should be discreetly numbered prior to lifting and relaid in the same position and orientation after the insulation works are complete.

Where possible, the reuse of boards that are in good condition is recommended to avoid waste. Skirting boards may also need to be removed and reinstated to make it easier to form airtight seals along the edges.

Ventilation openings in the subfloor void should provide unobstructed crossflow ventilation as specified in TGD C, with a free area equal to 1500mm^2 per metre run typical. If air bricks or vents already exist, avoid covering or damaging them. Additional ventilation openings may need to be installed and ventilation cores drilled through any tassel walls to ensure cross-ventilation. Additional airflow through the solum, in combination with airtight membranes, is effective in helping to reduce indoor radon levels in buildings and to prevent timber decay.

Suspended Timber Floors: Insulating from Below

Semi-rigid insulation may be easier to fit than soft rolls as it will hold in place better if cut or ordered to fit snugly between the joists. Timber battens may be fixed to the floor joists to hold the insulation in place.

The insulation should also fill the full depth of the joists, which are usually between 125mm and 225mm deep in traditional buildings. The insulation should be fitted tightly, with no air gaps present.

Mechanical fixing of insulation is required below the insulation to ensure it does not become dislodged over time. Friction fitting of insulation is not a reliable long-term solution due to the vibration and flexing that timber floors experience in normal use.

Netting is typically used to hold softer insulation in place. Where excessive wind is a concern, a wind-tight vapour-permeable membrane can be used to minimise thermal bypass of the insulation. The mesh or membrane should be stretched tightly and mechanically fixed. Cross-battens can also be fixed below the joists to support rigid or semi-rigid insulation boards.

Suspended Timber Floors: Insulating from Above

An airtight vapour-permeable membrane or netting may be draped between the joists to hold in the insulation in place. A batten can be fixed to the lower edge of the joists on both sides, creating a small ledge for rigid insulation to rest upon. Any gaps between insulation and joist should be packed with compressible insulation.

When the insulation has been installed, an intelligent vapour-control membrane should be installed between the insulation and the floorboards to control the movement of air from the room into the floor and vice versa. Sealing the membrane to the walls all round is very important to ensure airtightness. The membrane should be capable of variable vapour diffusion to ensure that moisture cannot be trapped.

If access is required to the services in the floor, an airtight access hatch should be installed and insulated as suggested for attic hatches. The hatch should be insulated to the same level as the rest of the floor to avoid surface condensation.

Figure 40: Slightly oversized batts of hemp insulation fit between joists over a wind-tight vapour-permeable membrane (blue) and beneath the intelligent vapour-control membrane (green). The vapour control membrane should be sealed to wall all round underneath the skirting. The solum should be cross-ventilated in accordance with TGD F and all pipework appropriately insulated

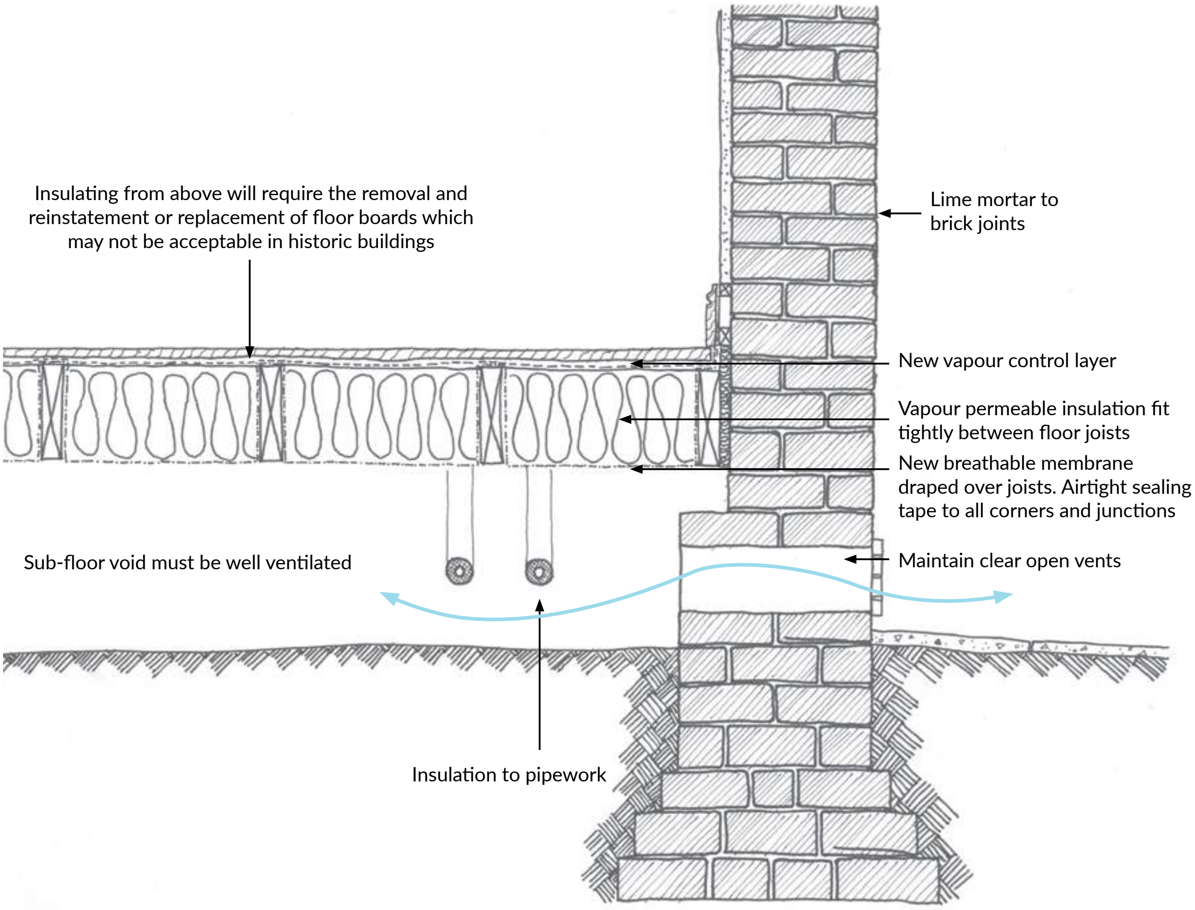


Figure 41: Typical suspended timber floor with insulation

thermal modelling may be able to suggest ways to improve the U-value of the floor by calculating the impact of vertical insulation to the perimeter of the floor instead of underneath it. The certified floor U-value arrived at by a registered thermal modeller can then be used in the DEAP/NEAP calculation.[59]

Where external walls are insulated below floor level (regardless of whether they are insulated above this level), this results in less heat loss through the floor. Extending this edge insulation down to foundation level increases the impact of the insulation. More than half of the total heat loss from a ground-bearing floor can be lost through the edge of the floor. Appropriate perimeter insulation can therefore avoid the need to disturb delicate floor finishes such as ceramics and flagstones, and contain floor interventions within the thickness of any wall insulation added. However, where the structure or site is protected under the National Monuments Acts, there may be archaeological implications to consider.

Where an uninsulated solid floor is being replaced, the new floor should comply with current building regulations. Where appropriate, existing floor finishes can be reinstalled on the new insulated floor.

The addition of insulation over an existing solid floor results in a raised floor level, which may not be feasible or desirable, even with thinner forms of high-performance insulation. When the floor level is being altered, other items that interact with the floor will need to be considered such as doors, skirting boards, staircases, thresholds, lintels and bulkheads.

Figure 42: Original stone flag floor

The quality of the elements to be modified and the amount of disruption to the totality of historic fabric caused by the new floor level must be taken into consideration when one is making a decision on floor insulation. However, as discussed previously, insulating floors can provide significant benefit in terms of reducing heat loss, therefore it is worth adding even a small amount of insulation to solid floors if possible.

[59] U-value of components involving heat transfer to the ground, e.g. ground floors with or without floor voids, basement walls, are calculated by the method specified in I.S. EN ISO 13370:2017. A solid thermal conductivity of 2.0 W/m.K should be used, unless otherwise verified

Solid Ground Floors: Preparation

Areas where air circulation is restricted, such as beneath cabinets, tend to have lower surface temperatures and are therefore at greater risk of consequential mould growth. If they are left uninsulated, the risk of mould growth increases due to a greater temperature differential. Particular attention is required at the floor perimeter, where surface temperatures are lowest and the risk of surface condensation is higher.

Careful assessment of the condition of the floor is required to determine its existing ground moisture resistance and likely ground gas resistance. Where high radon levels are indicated by a radon test result, it may be necessary to replace the existing floor entirely in order to install a radon barrier and standby sump(s), or other appropriate radon mitigation measures.

Any opening-up works or trial holes should be made in discreet locations, should not damage significant floors and should be filled afterwards with the original or like-for-like materials.

Where floors are replaced, consideration should be given to introducing underfloor heating to improve the efficiency of any heat pump used and to eliminate intrusive radiators.

Consideration should be given to reinstating any existing decorative floor finishes following the replacement of the floor. Where excavations for floor replacement expose shallow foundations, care will be needed to ensure that these are not disturbed during the work.

Where historically significant floors are present, consideration should be given to achieving the improved thermal performance required through introducing vertical edge insulation at the plinth externally. Internally edge insulation can be concealed under skirtings or finishes. A registered thermal modeller will be required to assess the resulting U-value to apply to the floor.

Solid Ground Floors: Installation

Where the existing floor is removed and a new floor is installed, the new floor will require a radon or damp-proof membrane to prevent the passage of radon gas and/or moisture from the ground below into the building. All requirements of the building regulations for new ground floors should be provided for.[60]

Vapour-permeable floors using certified materials are generally installed on an insulation layer of lightweight expanded clay aggregate or recycled foam glass aggregate, which also provides a capillary break. The new floor slab should be protected from frost or impact and allowed to cure for 2–3 weeks prior to the installation of a lime screed. Consideration should be given to installing underfloor heating within the lime screed to provide low-level background heating. Installation can vary and specifiers should follow manufacturers' recommendations. Note that all materials must be 'proper materials' in accordance with Part D of the Building Regulations.

Figure 43: Typical solid ground floor insulated slab. The ground level has been excavated with a new concrete slab, insulation and screed installed.

[60] See Government of Ireland (2014 and 2022)

3.4.4 Windows and Doors

Windows in traditional buildings were single-glazed and most often timber-framed, although metals including lead, cast iron or wrought iron were also used in frames. Windows and doors lose heat through the glass, through the frames and through any gaps that allow air infiltration, therefore focusing solely on the U-values of the glazing can be misleading. Windows with panes held in thermally poor frames (conductive heat losses) or in leaky frames (infiltration heat losses) or where the frames are installed without thermal isolation from the structure (installation heat losses) will all perform poorly.

In general, where original or historic windows and doors exist, the first option should be to retain them and improve their thermal efficiency. This usually is possible, even where they are in very poor condition and extensive repairs are required. In addition to protecting their architectural heritage value, this conserves the embodied carbon in the existing windows and avoids the new carbon emissions that would result from the manufacture, transport, installation and future replacement of the new windows.

Where a building is not subject to statutory protection and the proposed works would not require planning permission,[61] the building owner can choose to replace the existing windows in order to reduce heat loss or as part of a package of energy upgrading works. Replacement in such cases should ensure that the design and materials of the new windows are appropriate to the building and meet the thermal performance (and all other) requirements of the building regulations. In these situations, windows and doors may be replaced with new double- or triple-glazed timber framed units that are preferably compatible with traditional buildings.

In buildings where historic windows and doors are to be retained, repairs, draught-proofing, secondary glazing, shutters and curtains can all be used, in combination, to reduce heat loss and increase thermal comfort. Secondary glazing, or even secondary windows, can allow for the historic single-glazed windows to be retained while improving thermal performance. These should be detailed to ensure that the functioning of existing shutters/windows is retained. The Advice Series volume *Windows: A Guide to the Repair of Historic Windows*[62] should be consulted for general guidance on works to historic windows and doors.

Window, door or rooflight repair, even if extensive, should not trigger a requirement under building regulations to meet modern standards of energy efficiency, whereas replacement does. While competent joinery shops may be able to produce exact replicas of the existing windows, doors and rooflights, these are considered new components and, as such, each must comply with current building regulations. If the joinery supplier cannot provide the necessary independent test certification to attest to the new window, door or rooflight's compliance with current building regulations, appropriate secondary glazing, which meets current building regulations, used in combination with repaired and retained external windows can facilitate compliance while simultaneously preserving the external character of the building.

Alterations to, or the removal of, historic windows, doors and any special associated features or furniture within protected structures, proposed protected structures or buildings in

[61] See Planning and Development Act 2000 (as amended), Section 4(1)(h)

[62] Government of Ireland (2007b)

ACAs will materially alter their character and are unlikely to be considered acceptable. The local authority's architectural conservation officer should be consulted in the early stage of the design process for advice.

A study was carried out in Scotland to measure the effect of various thermal improvements to the centre-pane U-value of traditional windows.[63] The test window was a typical six-over-six pane timber-framed sash window with single glazing, which was in good condition but had not been draught-proofed. Thermal transmittance tests showed that while draught-proofing resulted in a negligible improvement to the U-value from 4.5 to 4.2W/m^{2}K, it reduced air leakage by 86%, from approximately 3.5 to 0.5m^3/h. Of the options tested, secondary glazing was shown to be the most effective measure, reducing overall heat loss through the window by up to 63%, with timber shutters reducing heat loss by 51%. Of course, the thermal benefit of internal shutters would generally only apply outside of daylight hours, or when rooms are not in occupation. The results of the study are shown in Table 10.

Where original or historic single-glazed windows are still intact, draught-proofing and reversible secondary glazing may be the most optimal and preferred option to improve the U-value of the window. It may also be a cost-effective option to improve the thermal performance of existing non-historic windows that are still within their useable life. As shown in the table above, secondary glazing in combination with internal shutters (insulated or uninsulated) or heavy curtains can dramatically improve thermal performance of the window and the comfort of the building's occupants while retaining the original window and glass panes.

Secondary glazing is typically single or double glazing within a metal, PVC or timber frame. It can range from simple systems using a magnetic or clip-in system[64] up to bespoke sliding or hinged units. Consideration should be given to whether the secondary glazing needs to be operable to allow for ventilation and whether it needs to be removable for cleaning or storage during warmer months. Choose a style and opening type that is visually appropriate to the character of the windows. If there needs to be a division in the panel, it should be sited behind the window's meeting rail.

Another option may be to replace the existing glass panes with higher performance glass. A number of systems on the market use either an insulating vacuum or gas-filled cavity between two panes of glass to improve the thermal performance by up to 50%. Historic glass should preferably not be removed to fit patented energy-conserving or solar control glass. The local authority's architectural conservation officer should be consulted if the building is a protected structure, a proposed protected structure or within an ACA before any work is commenced.

It is usually possible to significantly upgrade fanlights, overlights and sidelights for improved thermal performance by installing internal secondary glazing even to decorative and delicate lights. It is generally not recommended to install secondary glazing external to decorative lights as the space between the original glazing and secondary glazing can become quite warm, leading to the warping and deterioration of the lead or cast iron. Alternatively, fanlights, overlights and sidelights should be repaired to fit well within the frames to minimise draughts. Leaded lights or stained-glass panels should be repaired by

[63] Jenkins & Curtis (2021)

[64] Magnetic and clip-on secondary glazing is not included as part of DEAP/NEAP methodology and will not, therefore, impact on a building's BER but can improve thermal comfort

Table 10: Historic Environment Scotland study demonstrating the results of U-value testing for improvement measures to sash and case windows (Jenkins & Curtis, 2021)

Improvement method	Reduction in heat loss	U-values (W/m2K)*
Unimproved single glazing	–	5.5
Fitting and shutting lined curtains	14%	3.2
Closing shutters	51%	2.2
Modified shutters with insulation set into panels	60%	1.6
Modern roller blind	22%	3.0
Modern roller blind with low emissivity plastic film fixed to the window facing side of the blind	45%	2.2
Victorian pattern roller blind with plain fabric	28%	3.2
A 'thermal' honeycomb blind	36%	2.4
Victorian blind and closed shutters	58%	1.8
Victorian blind, shutters and curtains	62%	1.6
Secondary glazing system	63%	1.7
Secondary glazing and curtains	66%	1.3
Secondary glazing and insulated shutters	77%	1.0
Secondary glazing and shutters	75%	1.1
Double-glazed pane fitted in the existing sash	79%	1.3
Secondary glazing, double-glazed with aluminium frame to existing single-glazed timber sash and case	85%	0.8
Secondary glazing, double-glazed with timber frame to existing single-glazed timber sash and case	88%	0.6
Secondary glazing, single-glazed with timber frame to existing single-glazed timber sash and case	71%	1.5
Aerogel, 10mm, blanket fitted to timber window shutters	82%	0.4
Polycarbonate secondary glazing held with magnetic strips	56%	2.4

* These U-values are indicative and cannot be used for DEAP/NEAP calculations; however, where compliant calculations are undertaken in accordance with the DEAP/NEAP methodology, U-values similar to these may be attainable. Shutters and curtains are not included as part of DEAP/NEAP methodology and will not, therefore, impact on a building's BER but can improve thermal comfort.

Figure 44: Timber sash window with original glass panes

an experienced specialist using like-for-like materials and techniques.

The thermal performance of traditional buildings can be improved by reducing heat loss through draughts around doors and windows by fitting suitable draught stripping. A small amount of fabric loss may be required to install draught-proofing strips within the window or door frames. Visible draught-proofing strips would not generally be acceptable for protected structures. Timber doors and shutters can be improved with the application of a thin layer of high-performance insulation to the internal face of recessed panels. This may need to be finished with a thin plywood facing and new beading before being painted. Such a thermal upgrade may not be acceptable for original or historic doors within protected structures and a local authority architectural conservation officer should be consulted prior to works.

Beyond the U-value of the window or door, the conductivity of the frames, the continuity of insulation at frame/wall junctions and any air infiltration through gaps are important contributory factors to overall thermal performance of windows and doors. These contributions can all be modelled or measured, and results included in the DEAP/NEAP calculation to improve the accuracy of the BER.

Bespoke whole window or door U-value calculations are possible for traditional and upgraded historic fabric and can be undertaken by a registered thermal modeller. Thermal modelling can also confirm that works to existing windows or doors do not produce a 'new or greater contravention' of the minimum surface temperature requirement set out in Appendix D of TGD L.

Figure 45: Two-over-two pane timber sash window

Figure 46: Two-over-two pane timber sash window showing operable shutters

Draught-Proofing Windows and External Doors

Draughts result in heat loss and may make a room feel cooler than it is, therefore draught-proofing is usually the first option to consider for improving the thermal performance of windows in an older building. Draught-proofing will not improve the U-value of a window or door, but it will reduce heat loss by reducing air leakage, which can be measured by air permeability testing. The overall aim should be to gain control of the rate of ventilation in the room concerned.

The first step is to identify any air gaps around the windows, the doors and their frames, which can be draught-proofed, insulated and sealed. Existing window casements and linings can also be removed and reinstated after the installation of wall insulation. The general condition of the existing windows, doors and any timber noggins, lintels and the like should be assessed while the linings are removed to determine if repairs are necessary.

External doors in older buildings may have become ill-fitting over the years and are often draughty. Traditional doors can be draught-proofed in the same way as windows and various draught-proofing strips are widely available. The bottom of external doors can also be fitted with a weatherboard or inset drop-seal provided this can be achieved without damage to a historic door. Thin high-performance insulation can be added on the inside face of door panels and held in place by timber linings with timber beading to improve U-values. Letterbox brushes or flaps can be fitted to reduce draughts.

Where gaps and cavities exist between window frames and the surrounding structure, as well as behind shutter boxes or panelling, the insulation of these areas can significantly improve both airtightness and thermal performance and reduce the risk of internal surface mould growth and/or surface condensation. Where insulation is installed in these areas, an airtightness membrane, which may also act as a vapour control layer, should be installed to the warm side of all new insulation and sealed to the internal wall finish, as well as being taped or sealed to the window frame's internal surface. Insulating these areas without the inclusion of an airtightness membrane to the warm side of the insulation may lead to increased interstitial condensation. The membrane can also help to provide continuity of the airtightness sealing between window frame and wall surfaces.

In the case of some particularly old, delicate or valuable window frames, cutting grooves to insert draught proofing will not be appropriate and expert advice should be sought on alternative methods of upgrading.

Routing out grooves in a timber frame to fit draught strips is irreversible. It can cause damage to joints, especially in sashes with very thin frames. If there is a wide range of gaps in the windows, several solutions might be necessary. Gaps can be seasonal in timber windows, as timber expands when damp.

Moulded mastic sealants can be used to draught-proof metal windows. After application the mastic moulds itself to the shape of the gap. Steel windows may have distorted through paint build-up or corrosion and gaps may have been created. It is important to treat the cause before specifying appropriate draught-proofing. To prevent casements being distorted through forcing them to close, use the slimmest draught strips adequate for the situation.

Care should also be taken to ensure that existing ironmongery such as handles, catches and hinges will continue to function correctly following draught stripping.

Secondary and Replacement Double Glazing

Secondary glazing will significantly upgrade the energy efficiency of historic single-glazed windows. Secondary double-glazing can provide even more improved energy efficiency and may be considered as a more robust and long-lasting solution. All secondary glazing systems must be well sealed to control condensation forming on the existing window panes and protect the historic frames from water damage. Any new intervention should retain the function of the existing window and its shutters.

Secondary single glazing usually comes in glass, perspex or polycarbonate panels, which are usually installed within a separate frame or onto adhesive/magnetic strips. It is good conservation practice for secondary glazing to be easily removable and reversible to allow for cleaning and removal during summer months to facilitate natural ventilation and cooling. While secondary glazing is effective, it should be in keeping with the character of the windows and room in which it is fitted. Formal rooms or rooms with high-quality decorative finishes may be compromised by the fitting of secondary glazing.

Secondary glazing should always be fitted in such a way that it is still possible to use existing shutters. Slim-line secondary glazing is available that can be fitted in place of the staff bead between the bottom sash and the shutters. This allows the shutters and curtains to be used at night when outside temperatures are lower.

Where the existing non-historic glass panes are to be replaced, vacuum-insulating double-glazed panes should be considered to reduce the overall window U-value and increase the surface temperature of the glass surfaces. A specialist in traditional window repairs should be able to determine whether the existing frames and glazing bars will be able to handle the additional width and weight of the new sealed double-glazed panes.

Certified U-values for composite systems that include secondary glazing, or for replacement glazing solutions, may be calculated in accordance with ISO 10077-1&2 by a specialist, if required.

Replacing Windows and External Doors

Generally, replacement windows and doors should seek to match the originals in design, fixing, method of opening and material.

For metal windows, steel replacement double-glazed windows are available, although they can be expensive for individual replacements. Aluminium may be acceptable as an alternative if original patterns and sections can be successfully replicated. Bear in mind that new metal window frames will need to meet the minimum surface temperature requirements of building regulations and will invariably need to be thermally broken between inside and outside.

When installing new windows and doors, it is important to make sure that the area around the window or door is properly draught-proofed and well maintained. If original frames are being kept, the new windows and doors must fit the frame perfectly to avoid any gaps.

Replacement windows, doors and rooflights will need to meet the performance standards set out in TGD L, regardless of their construction or appearance. This may require specific testing and NSAI certification.[65]

[65] Subject to exemptions for protected structures and extensions to protected structures: see paragraph 0.6.1 of TGD L

Figure 47: Aluminium draught strips can be seen to all sides of this door. Internally there is an insulated curtain

Figure 48: Carefully designed secondary glazing. Double-glazed secondary glazing is also available

Figure 49: Discreet draught-proofing brush on a historic window

3.4.5 Solid Walls

According to estimates, external walls are responsible for 35% of heat loss in traditional buildings, therefore internal and/or external wall insulation could significantly improve the energy efficiency of the building. Solid wall insulation can be a high-risk retrofit option, however, and should be one of the last options considered after less intrusive energy-efficiency upgrades have been assessed. To mitigate risk, hygrothermal risk assessment should be undertaken to understand the hygrothermal properties and performance of the existing wall and assess how these will be affected by the proposed insulation. It is also imperative to research, evaluate and understand the integrity of the traditional fabric and finishes to determine what should and should not be disturbed from an architectural heritage perspective, having due regard to any protections in place.

Recently, heat flux monitors have become available that can be used in accordance with ISO 9869 to estimate wall U-values. Such in-situ measured U-values are not currently acceptable for input to statutory calculations, but they can provide useful information for projects that do not require a statutory certificate, e.g. BER. For more information see BR443.[66]

If the building fabric is vapour-permeable, insulating materials and surface coatings should, in general, also be vapour-permeable to allow moisture within the wall to evaporate through the external or internal surfaces. Water is a conductor, therefore when a wall becomes damp, it conducts heat to outside at a higher rate compared to a dry wall. Trapped moisture can also lead to mould growth and to the decay of timbers. Existing vapour-closed finishes such as cement render, cement mortar and paints, where they prevent the proper drying out of the wall and can be successfully removed without damage to the wall, should be removed and replaced with capillary active materials before wall insulation is applied.

Studies have found that traditional solid walls often perform better thermally than commonly thought and may perform better than the default 2.1W/m^{2}K U-value assigned to solid walls in DEAP/NEAP.[67] Therefore, it is recommended to calculate the U-value based on the thermal conductivities and thicknesses of the component parts of the wall elements to inform decisions on meeting energy-efficiency targets for the building (see Section 2.2.7 for further guidance). At the time of writing, research has been commissioned by SEAI to establish U-values for a variety of traditional solid walls types found in Ireland.

3.4.5.1 Internal Wall Insulation (IWI)

IWI involves the installation of insulation materials to the internal surface of the external walls (the envelope of the building), increasing the wall depth and thus reducing the floor area of insulated rooms, which may sometimes be a prohibitive factor for small dwellings. Planning permission may be required for IWI in a protected structure or proposed protected structure. Where a building is not protected but retains significant internal plasterwork and features that are worthwhile to retain, a conservation professional should be consulted before adopting an IWI solution. IWI is usually the preferred option for buildings with exposed brick, ashlar stone and/or interesting external detailing or for buildings where only the façade is protected.

[66] Anderson and Kosmina (2019)

[67] Baker (2011)

IWI can improve the thermal performance of solid walls but may, if not carefully specified, detailed and executed, introduce significant moisture-related risks.[68] IWI will insulate the wall from internal heat sources, thus creating a greater temperature differential between the masonry wall and the new internal surface of the insulation. It is therefore particularly important that the insulation is vapour-open to allow any moisture to dissipate.

It is recommended that hygrothermal risk assessment in accordance with I.S. EN 15026:2007 is carried out before IWI specifications are finalised. The aim should be to improve the energy efficiency as far as is reasonably practicable. However, the work should not prejudice the character of the building or increase the risk of long-term deterioration of the building fabric.

The installation process for IWI can be disruptive, requiring the careful removal and reinstallation of joinery (including skirting boards, panelling, dado rails, window surrounds, internal shutters and the like) and the relocation, or reinstatement, of architectural features such as cornices. IWI will usually involve disruption to the users and vacation of rooms while works are being carried out.

Internal Wall Insulation: Preparation
IWI should only be considered once the condition of the exterior wall, roof, rainwater goods and ground areas is satisfactory. Any repair work to the roof, walls and gutters should be carried out first to ensure the wall is dry prior to insulation. If insulation is added before these components are dealt with, it can exacerbate damp issues.
Cement renders and pointing should be removed completely and replaced with lime-based products where possible. Where this is not possible, a detailed hygrothermal analysis of any proposed insulation will be required to establish that the proposed insulation does not increase the risk of causing long-term damage to the building fabric. Depending on the system used, later internal plasters (e.g. gypsum- or cement-based plasters) may have to be removed before IWI is added.
Where possible, building services should be removed and relocated on the warm side of the insulation.
Alterations may need to be made to existing joinery such as door and window architraves, skirting boards, panelling and dado rails to accommodate insulation. These may need to be removed and reinstalled after completing the insulation.
Decorative architectural features such as plaster cornices will be concealed or lost by the installation of IWI. This will be a prohibitive factor if the feature is to be retained or where the building is a protected structure or proposed protected structure.
It may be necessary to remove window cases and door frames to allow for the insulation of the reveals. A qualified joiner will be able to adjust and reinstate the historic joinery elements to suit.
Where default U-values are not used, it is recommended to either calculate the U-value of a solid wall in accordance with I.S. EN ISO 6946:2017 and BR443 or model it in accordance with I.S. EN ISO 10211:2017. Multiple tests/calculations may be required if the external walls vary in materials or thickness. To gain a better understanding of the wall's current thermal efficiency, it is also possible to undertake in-situ U-value measurements in accordance with ISO 9869-1:2014 prior to the specification of insulation. Note that in-situ U-value measurements are not currently acceptable for input into statutory calculations, e.g. BERs.

68 Arregi and Little (2016)

Internal Wall Insulation: Installation

It is preferable to apply insulation directly to smooth masonry or to lime-based plaster, which will reduce the risk of moisture build-up within the wall. Depending on the wall and the insulation to be used, a plaster layer may need to be added to the internal surface of the walls to create a smooth surface to which to apply the insulation.

All window and door reveals should also be insulated as much as possible and be taped around the frames to ensure an airtight fit and uniformity to keep them from acting as a thermal bypass. To demonstrate this point, one study found that 20mm of IWI with insulated reveals would achieve a similar transmission heat transfer coefficient to 140mm of IWI without insulating the reveals when applied to a 500mm thick solid brick wall in a mid-terrace building.[69] Insulation continuity is more important than insulation thickness.

Insulation should be installed along the window and door reveals wherever possible to minimise the risk of thermal bridging and heat loss through these areas. Where space is limited due to the window or door joinery, an insulation with a better lambda value may be preferred. Insulation should be continuous from the internal face of the wall around and across the reveal.

The wall below windowsills is often thinner than adjacent walls and may require a thicker layer of insulation or an insulation with a better lambda value if space is limited. Sill boards may need to be extended to accommodate the change. U-value calculations and thermal modelling can be used to determine how much insulation is required.

At intermediary floor junctions, the insulation should be fitted between and taped around all joists where they meet the wall, ensuring an airtight fit. This will require the removal of the perimeter floorboards during the works. Thermal modelling may be required if insulation cannot be extended between intermediary floors.

It is important that the insulation be extended through the depth of the floor, fully filling the floor void, and connecting with the insulation above and/or below. For suspended timber ground floors, insulation should extend as far down as possible and at least to the full depth of the floor joists. Thermal bridge modelling may be used to ensure the minimum surface temperature is achieved at ground floor junctions and avoid the staining often (wrongly) attributed to so-called 'rising damp.'

In buildings with solid floors, the perimeter of the floor can be cut back to allow vertical insulation to go down to at least external ground level and, if possible, below external ground level. Thermal modelling can then be used to calculate the improved overall floor U-value. The joint between solid floor and wall can be sealed with a radon-proof tape to prevent increased radon infiltration.

If insulation boards are used, these should fit tightly and neatly against each other and other components to avoid any gaps or thermal bypass. Tongue-and-groove boards can be used to achieve a more airtight fit. All joints and corners should be taped using proprietary airtightness tapes. If a vapour control membrane is to be used, it is recommended to use a variable vapour diffusion resistance product, which will allow vapour to be released in both directions depending on the season; otherwise moisture can become trapped in the wall. Hygrothermal risk assessment modelling can determine where a variable diffusion resistance or fixed vapour resistance product is most suitable.

IWI may need to extend approximately 1500mm back on abutting internal masonry walls to ensure the walls do not act as thermal bridges. Insulating lime plaster or tapered insulation boards can be used to visually blend the insulation with the existing wall finishes. Thermal modelling can be used to determine the extent of any flanking wall insulation required to ensure no 'new or greater' contravention of building regulations in relation to surface condensation.

After installation of the insulation and membrane (if required), all services should be relaid within a service void. Doing this means that the insulation or membrane is not penetrated, which can reduce its overall thermal performance. In situations where a lime finish plaster coat is directly applied to the insulation system, e.g. insulating plasters, calcium silicate boards or wood-fibre boards suitable for finish skim coat, this may not be necessary.

All IWI products must be 'proper materials' as defined in TGD D and applied/installed strictly in accordance with their certification and the manufacturer's instructions.

[69] Marincioni et al. (2016)

Figure 50: Tape to sash frame prior to application of IWI to ensure an airtight fit (Photograph by Con Brogan for OPW)

Figure 51: Woodfibre insulation board being prepared prior to application of finish coat

Figures 52 and 53: Insulating cork lime plaster sprayed on an uneven wall with reinforcement mesh applied below finish coat (Photographs by Con Brogan for OPW)

Figure 54: Woodfibre boards applied to walls and carefully fitted around and between floor joists to ensure continuity of insulation

Figure 55: Build-up of lime mortar to level uneven surface prior to application of woodfibre board

Figure 56: Plaster spraying machine

Insulation boards should fit tightly and neatly against each other and other components. All joints and corners should be taped. Insulating plasters may not require airtightness tapes.

Reveals should be insulated to at least the extent necessary to ensure that the critical surface temperature is achieved, see TGD L, Appendix D for details.

Depending on wall and insulation type, a lime plaster layer may be required to create a smooth suface to receive the insulation layer. Note: gypsum-based plaster should not be used on the cold side of insulation due to its moisture retention properties.

Wall insulation should be continuous through the intermediate floor zone to prevent surface condensation forming on uninsulated wall surfaces within the floor zone. Taping around joists will reduce the risk of exfiltrated warm air condensing in the vicinity of joist ends embedded in the wall.

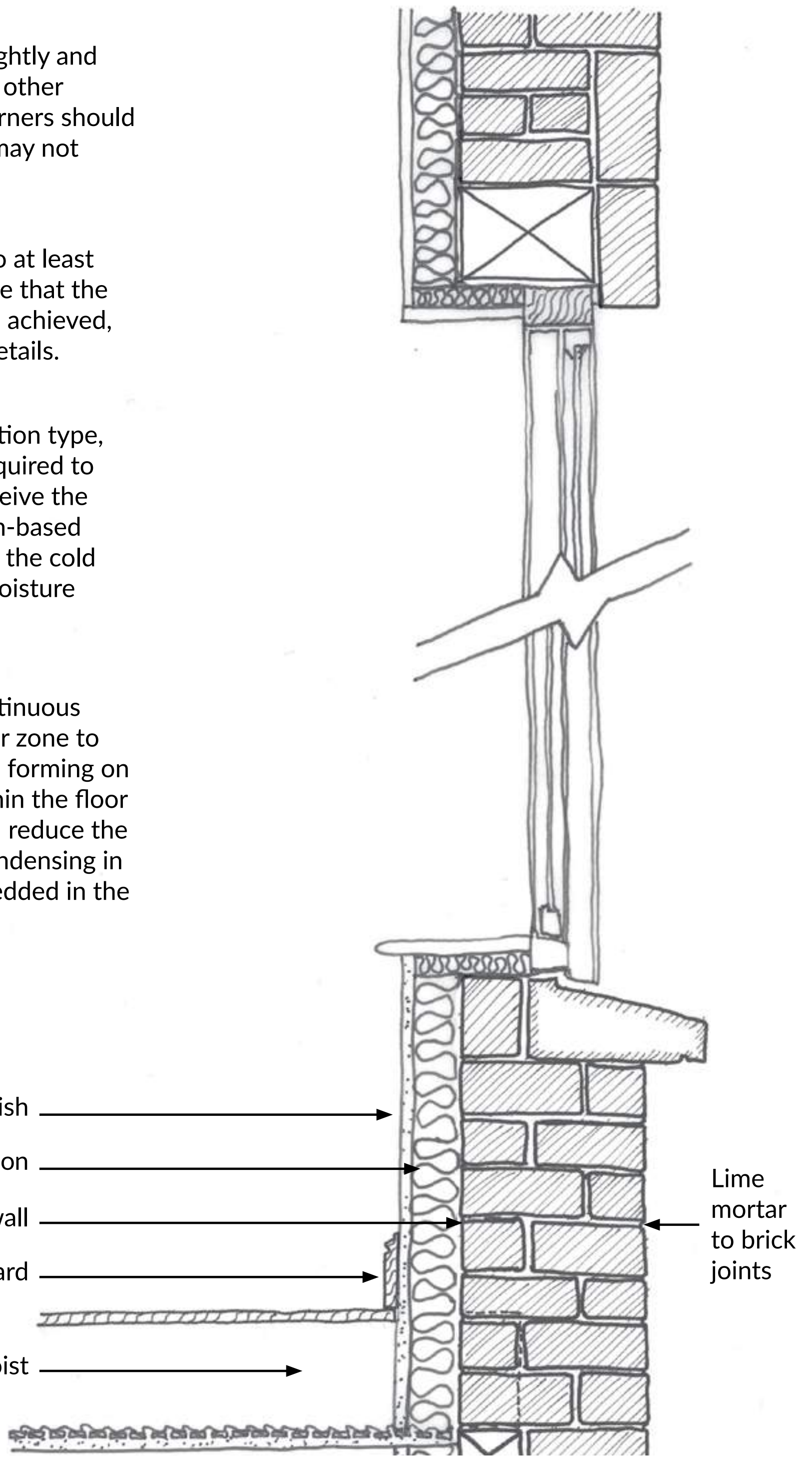


Figure 57: Typical internal wall insulation measures

Internal wall insulation to extend into the joist zone but not through the lath and plaster ceiling. Tape joist to insulation or vapour control layer if present.

A lime plaster scratch coat should be applied to the existing solid wall depending on the insulation requirements to assist in application.

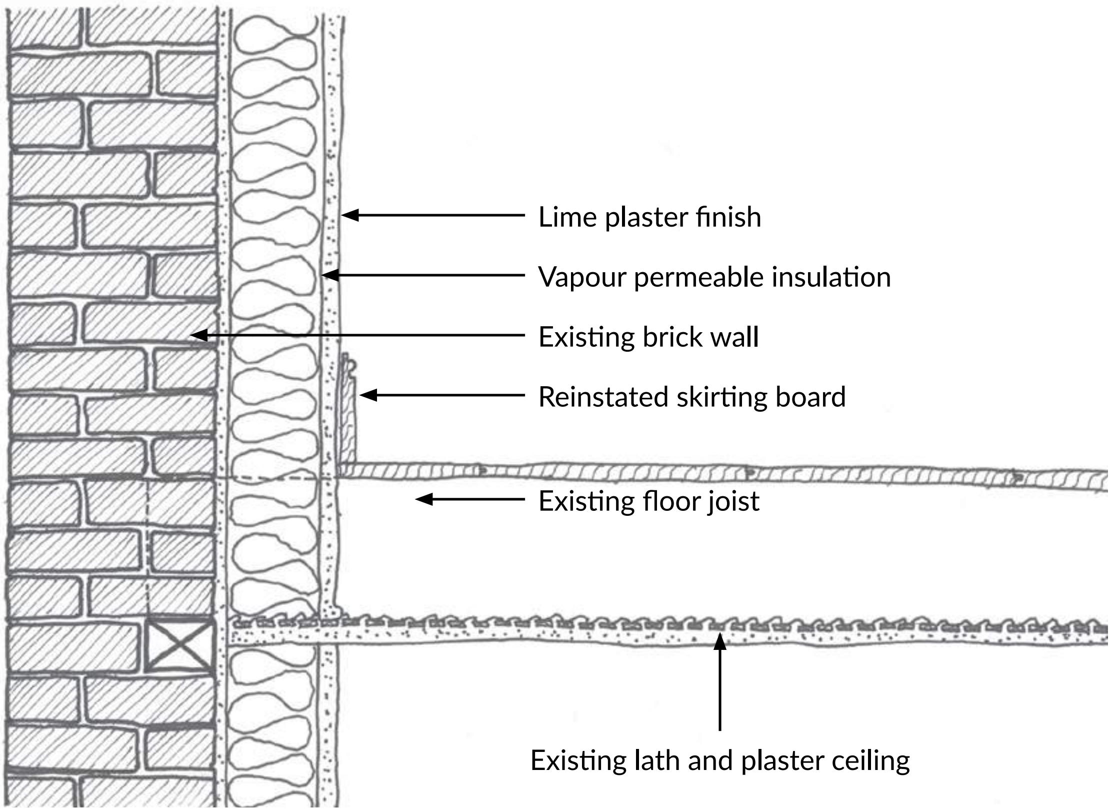


Figure 58: Intermediate floor – internal insulation

3.4.5.2 External Wall Insulation (EWI)

For a traditional building that does not have a significant exterior that is to be protected, the application of EWI may be possible. The installation process for EWI can be less disruptive to the building occupants, but it may require the extension of the roof eaves as well as the replacement or modification of windowsills, decorative features, gutters and downpipes, soil and vent pipes and other services.

EWI will insulate the wall from external elements, including the warmth of the sun, but will keep the temperature of the masonry wall closer to internal temperatures all year round. After EWI is applied, the wall will only absorb heat from the internal heat sources and solar gain through the windows. To maintain safe moisture levels, it is important that vapour-permeable insulation be used to allow the movement of moisture from the interior to the exterior.

Figure 59: Insulating render spray applied on external walls. Spraying can use less material than application by trowel because the plaster is not being compacted.

The risk of thermal bridges must be considered carefully in the design and specification of EWI to ensure insulation continuity and avoid surface condensation. Thermal bridge modelling may be required to confirm that EWI will not cause surface condensation at junctions.

The following benefits are associated with EWI.

- The exterior walls are evenly covered, and thermal bridging is minimised.
- The benefits of thermal mass and moisture buffering provided by the solid masonry wall are retained.
- EWI significantly reduces the risk of interstitial condensation.
- The masonry wall remains heated, dry and protected from the elements.
- Timber elements embedded in the walls are protected from moisture.
- The internal finishes and room sizes are not altered.
- Carefully considered EWI installations can be successfully reversed, if required.

EWI may change the external appearance of a building and where it would render the structure inconsistent with the neighbouring buildings, planning permission may be required. Early consultation with the local authority is recommended.

Planning permission is generally required for the application of EWI in the case of a protected structure, proposed protected structure or a building within an ACA and should only be granted after careful consideration of all the implications. EWI may not always be appropriate for buildings with external decorative details or features.

In the case of terraced or semi-detached buildings, careful consideration needs to be given to the risk of thermal bridging at party walls and how this can be mitigated. In addition, external detailing at these junctions needs to be very carefully considered from an aesthetic point of view.

External Wall Insulation: Preparation
Downpipes and waste pipes and other services may need to be removed and refitted further away from the wall to allow the insulation to be fitted behind them.
The condition of the external face of the building needs to be assessed before EWI is applied to determine if repairs are required. Existing render may need repair/replacement to ensure a smooth surface for the insulation to be applied to. Vapour-closed renders (such as cement) may not need to be removed prior to the application of EWI because the entire wall will now be warm and less susceptible to interstitial condensation.
Priority should be placed on maintaining the original window line, where surface condensation risk analysis demonstrates that this presents no risk and is compliant (where applicable) with the requirements of Appendix D of TGD L and BRE information paper IP 1/06.[70]

External Wall Insulation: Installation
Vapour-open insulations are recommended for use with solid masonry walls to minimise condensation-related risks.
Reveals should be insulated as much as possible. A better performing insulation may be required if space is limited. A thermal model can determine if the proposed insulation will be sufficient. Insulation around the window and door reveals should meet the frames. Airtightness tapes can be used on the joints between windows and masonry to minimise air leakage.
Consideration should be given to the effect of EWI on the character of the building and on any external decorative details or features. Cornices, dentils, sills, etc. can act as cold bridges if left uninsulated. A thermal model may be required to determine if retained uninsulated string courses, dentals, brackets and similar features pose a risk of surface condensation on the inside of the building.
All EWI products must be 'proper materials' as defined in TGD D and applied/installed strictly in accordance with their certification and the manufacturer's instructions.

[70] Ward (2006)

3.4.6 Airtightness

With all of the above upgrading measures, airtightness is an essential component in order to protect the building fabric from the effects of interstitial condensation caused by warm moist air leaving the building through air leakage pathways (see also 2.1.4.1). Where interstitial condensation occurs on structural elements such as lintels, timber framing members and wall ties, long-term exposure may lead to deterioration of the structure. Air leakage also leads to excessive heating requirements and associated emissions and to poor thermal comfort.

Traditional buildings typically use wet-applied lime plaster to ensure airtightness.[71] Where the plaster finish is intact, relatively high levels of airtightness have been found through air permeability testing. Conserving, repairing and reinstating the lime plaster finishes will ensure the continuity of the airtightness layer.

Air leakage is additional air infiltration in the form of draughts, which should be eliminated as far as practically possible. This does not include any purpose-provided permanent ventilation, which should be maintained, where required.

Air permeability tests can be carried out on the building to determine the air change rate before and after upgrade works to check the quality of the works, allow for remediation and provide the evidence necessary to improve the BER rating.

Table 11: Checklist of retrofit measures to achieve improved airtightness

•	**All external doors fitted with integral draught seals and letter box seals**
•	**All windows fitted with draught seals**
•	**Internal and external sealing around door and window frames**
•	**Effective edge sealing of suspended floors**
•	**Careful sealing of junctions between building elements such as walls to floors and walls to ceilings**
•	**Careful sealing around attic hatches**
•	**Careful sealing around internal soil and waste pipes**
•	**Careful sealing around domestic water and heating pipes passing into ventilated spaces**
•	**Careful sealing of all service penetrations in the building fabric (electricity, gas, water, drainage, telephone, TV aerial, etc.)**
•	**Careful sealing of all cable conduits for light switches and power sockets**
•	**Ability to close trickle vents and other ventilation devices (where appropriate)**
•	**All cable entry for ceiling lighting carefully sealed. Recessed lighting should not penetrate ceilings separating attic spaces from rooms unless suitably sealed.**

[71] See BS EN 459-1:2015 *Building lime definitions, specifications and conformity criteria*

3.5 Other Efficiency Measures

There are opportunities to improve energy and resource efficiency of traditional buildings beyond fabric upgrades. These can help to bring a traditional building's energy rating up to a B2 standard, and they are typically low-cost and easily implementable measures, because they generally do not affect the character of the building. These should be considered among the measures to be adopted in any energy-efficiency upgrade.

3.5.1 Lighting and Lighting Controls

Many traditional buildings were designed to optimise the use of daylight, reducing the need for artificial lighting. Upgrading light fittings and controls can significantly reduce the use of electricity in buildings. Energy savings are typically higher in buildings other than dwellings due to the greater proportion of energy used for lighting in these buildings. This is a measure that is often considered when carrying out upgrading works to achieve an improved BER.

Changes to lighting systems can be low-impact from a building fabric perspective and can be undertaken in advance of a wider renovation. However, if a major renovation is taking place, TGD L specifically requires that general lighting systems in buildings other than dwellings be upgraded where they are more than 15 years old, or have an average lamp efficacy of less than 40 lamp-lumens per circuit-watt as defined in NEAP and serve areas greater than 100m^2. Where original light fittings are present, it may be possible for these to be rewired and re-lamped to maximise energy efficiency without loss of historic character.[72]

The first step to energy-efficient lighting is to design the lighting installation in a way that meets all of the users' needs for the space under consideration. Recommendations for appropriate illuminance values and other lighting requirements may be found in I.S. EN 12464-1:2021, and in the *SLL Code for Lighting*[73] which provides practical advice on how to design lighting for a number of different applications.

Installing smart controls will yield additional energy savings by taking account of outdoor brightness as well as occupation, and will ensure an optimal balance of illumination and energy efficiency.

TGD L also provides guidance on the standard required for a lighting system's efficiency, as follows:

- efficacy (averaged over the whole area of the applicable type of space in the building) and controls in Table 8 Column 3 of TGD L; or
- maximum Lighting Energy Numeric Indicator (LENI) (kWh/m^2/year) listed in Table 9 of TGD L. LENI is based on BS EN 15193:2007 *Energy Performance of Buildings – Energy Requirements for Lighting*. It should be calculated using the procedure in Appendix F to meet the maximum values in Table 9 of TGD L.

It is important to understand that lighting technologies change frequently and any new system should be designed and installed in line with the principle of minimal intervention and should be reversible without causing damage to the historic fabric; for example, the damage that would be caused to lath-and-plaster ceilings to drill for inset downlighters is irreversible.

[72] See also: https://historicengland.org.uk/advice/technical-advice/building-services-engineering/internal-lighting-in-historic-buildings/
[73] Howard (2022)

3.5.2 Controlled Ventilation

In most traditional buildings, ventilation is provided by some or all of the following:

- windows and doors providing purge ventilation and a means of cooling
- background ventilation through purpose-provided wall vents, roof stack, lead- or copper-covered louvred timber vents, air bricks, grilles, etc.
- vent grilles or air bricks for heating appliances, and chimneys

The focus of energy-efficiency upgrading should therefore be to retain and exploit these existing design features wherever possible.

Purpose-provided ventilation should be maintained when it is still required, whereas air leakage should, as far as practically possible, be eliminated (see Section 3.4.6). Infiltration, i.e. air leakage through gaps and cracks in the dwelling structure, is not controllable by the dwelling occupants and may cause draughts, resulting in poor thermal comfort.

Existing purpose-provided ventilation should generally be retained and adapted. Where not provided for, designed ventilation should be added to control condensation, remove contaminants and provide for good indoor air quality.

Deliberately designed pathways, such as air bricks in floor spaces, were often installed to provide 'make-up' air to chimneys to ensure their proper functioning. Where chimney flues no longer contribute to the ventilation system, it is important to address any 'make-up' air pathways provided to avoid them merely becoming sources of uncontrolled infiltration.

The installation of room-sealed heat emitters, e.g. stoves, can be used to convert low-efficiency open chimneys to higher efficiency controlled flues. These may require a permanently open TGD J-compliant vent in each room where any new combustion appliance is installed to comply with the requirements of Part J and the provisions of TGD J. The highest efficiency room-sealed combustion appliances incorporate ducted ventilation systems connecting directly to outside. This may not be an appropriate solution for all historic buildings.

Figure 60: Copper-covered dome over louvred timber vent

3.5.3 Bioclimatic Design Principles

Bioclimatic design means ensuring that the fabric of buildings is designed to effectively mitigate local climate, orientation and site conditions using local materials to maximise comfort for occupants with minimal use of energy in construction and operation. Traditional buildings often portray many of the principles of bioclimatic design in their location, orientation and overall design.

Bioclimatic design principles for heating and cooling, and exposure to wind and rain, are introduced below.

Figure 61: Sunlight streams in through large, single-glazed, west-facing windows, maximising solar gain; however, it also brings about a need to protect historic furnishings and contents from damage caused by both ultraviolet and visible light

3.5.3.1 Exposure to Wind

A building's exposure to wind will increase or reduce the rate of heat loss: essentially, the windier the location, the greater the heat loss. While the direction of wind changes, knowledge of prevailing winds can help to determine where to put the weaker elements of the design, e.g. doors. The importance of achieving shelter from cold and damp wind has traditionally been understood; the traditional selection of a location for a dwelling was often in the lee of a hill and, equally importantly, not in a hollow prone to frost. Where natural features did not provide sufficient protection, shelter belts of trees were often planted.

Upgrading windows and doors can significantly reduce infiltration heat losses. Addressing airtightness will further improve thermal comfort and reduce heat loss.

3.5.3.2 Exposure to Driving Rain

A wall's construction, materials and exposure to driving rain can affect the level and depth of dampness within it. In traditional buildings, the thick solid masonry walls were designed to provide a sufficient barrier to the moisture, allowing drying to occur before the moisture reached the interior face of the wall. A vapour-permeable lime render aids drying of the moisture to the external air, while internal lime plaster permits drying to the inside, when conditions allow. Limewash was also traditionally used as an important means of protecting lime renders and mud and rubble walls from the driving rain, and was often reapplied annually.

It is important that the traditional external weathering of walls be maintained and repaired (e.g. brickwork repointed and render repaired, string courses, drips, sills, copings and plinths all kept free of plant growth or other obstruction) to prevent long-term damage to the fabric.

If the existing external envelope consists of modern cement or other later impermeable render, efforts should be made to restore the external envelope to its traditional permeable condition to enable the wall to dry out externally. Impermeable external coatings, including paints and cement washes, should be avoided as they will tend to trap moisture.

The conditions around the base of the walls will also affect rainwater absorption. The ground around the building would have traditionally been kept moisture-permeable or sloped away from the building to allow the absorption or dispersal of rainwater. The external ground level would have been kept lower than the internal floor level to protect from damp and flooding.

When vapour-permeable render, roof overhangs, drips and string courses were insufficient to achieve an acceptable moisture balance in solid walls, traditional solutions such as hung slate were effectively applied to vulnerable areas.

3.5.3.3 Passive Heating

Traditionally windows were provided exclusively to provide daylight. These can be upgraded to counteract the losses associated with single-glazed windows by adding secondary glazing. During daylight hours, buildings gain heat from the sun through windows. The amount of heat gained depends on the orientation, time of year, amount of direct sunlight or cloud cover, type of glass in the windows and nature of the materials within the building.

Solar gain can also associate patterns of use with activities corresponding to periods of sunshine; generally, bedrooms and kitchens facing east benefit from the morning sun and living rooms and dining rooms facing west benefit from evening sun.

3.5.3.4 Passive Cooling

Traditional buildings generally do not require mechanical cooling. They were designed and built before air-conditioning was invented and were intended to maintain acceptable internal conditions via passive and active interventions. The thermal mass of traditional solid walls tends to buffer temperature changes, with open windows and natural ventilation providing enough of a cooling effect to maintain comfort levels. A traditional vertically sliding sash window offers a highly adjustable ventilation solution, with its top and bottom opening creating an optimum circulation of internal and external air. However, these buildings do require active management by occupants; for example, opening windows in the evening to let in cool air and drawing the curtains or closing shutters during the day to avoid excessive solar heat gain.

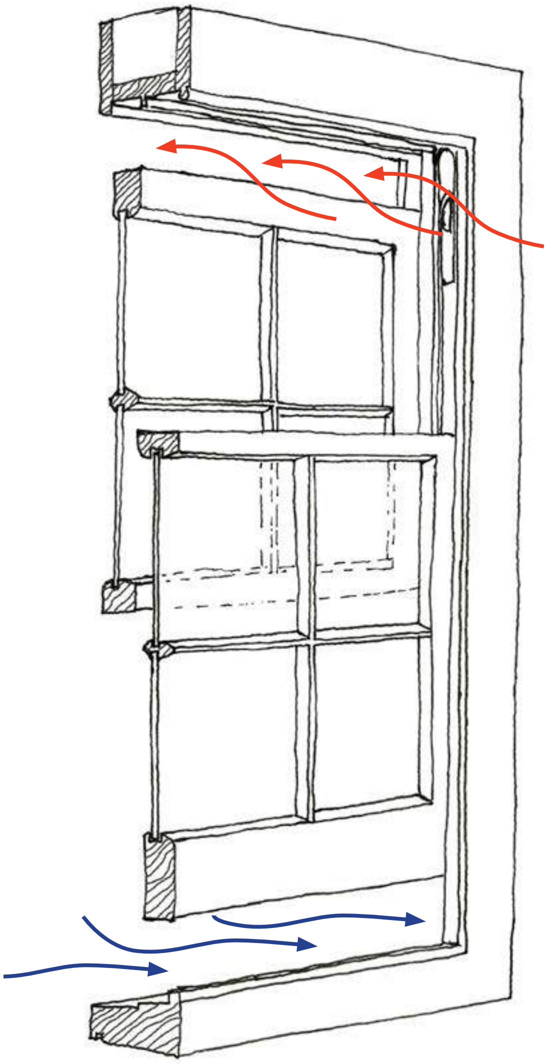


Figure 62: Timber sash window showing hot and cold airflow

The focus of energy-efficiency upgrading should therefore be to retain and exploit these passive design features wherever possible.

Projected climate change in Ireland means that warming during the summer will likely increase by 1–2·4°C, which may increase the need for cooling in some buildings during these months. Additional overheating mitigation measures might include the installation of internal solar control blinds or external traditional low-energy, low-carbon retractable awnings set within the window reveal to shade the glass. Such traditional solutions were used in the past.[74] Any potential changes to the external appearance may require planning approval.

3.5.4 Smart Heating Controls

Smart heating controls that respond to temperature sensors ensure more comfortable environments with fewer temperature fluctuations. They may also reduce the run-time of some heating systems compared to manual controls, particularly on buildings that are only occupied on weekdays, as temperature requirements for vacant buildings are lower.

It is crucial that any smart control system is correctly demonstrated to the building occupier/responsible person, rather than relying on an instruction manual. Lack of understanding of control systems frequently leads to inefficiency of use. When a building

[74] Pender (2021)

undergoes major renovation, the building owner should be provided with sufficient information about the fixed building services and their controls so that the building can be operated so as to use no more fuel and energy than is reasonable.

Smart heating controls should be considered whenever a heating system is being replaced and can further improve the BER of a building. For buildings with a heat generator with an effective rated output for space heating purposes of over 70 kW, a building automation and control system should be installed in accordance with the guidance provided in TGD L.

3.5.5 Pipe Insulation

Insulated pipework results in lower distribution heat loss and therefore greater efficiency in a heating systems and more control of overheating. Unless the heat loss from a pipe or duct carrying hot water contributes to the useful heat requirement of a room or space, the pipe or duct should be insulated as described in TGD L. Primary pipework (between heat generator and any storage cylinder) should be insulated whenever a heat generator is replaced or as part of a major renovation.

Water pipes and storage vessels in unheated areas, e.g. attics and subfloors, should be insulated to protect against freezing. Useful guidance relating to insulating cold-water service pipes and cold-water storage cisterns is provided in TGD G.

3.5.6 Maintenance Schedules

Regular maintenance of building services results in higher efficiency and prevents problems before they occur. Maintenance is frequently overlooked as an efficiency measure, but is often cost-neutral or better, and reduces the risk of damage to the overall building. A coherent and well-considered maintenance plan is advised as part of any renovation project. Regular maintenance will reduce the need for expensive repairs and can provide significant cost savings in terms of operational energy use.

In addition, the development of a coherent and well-considered maintenance plan for the upkeep of these repair measures is strongly recommended so that the groundwork for future maintenance of further upgrade works is established before proceeding with them.

3.5.7 Fittings and Appliances

Depending on the building usage, a significant proportion of energy may be used by inefficient appliances and fittings. Low-flow taps and showerheads, boiling water taps and A-rated or better appliances are among measures that should be considered when replacing appliances and fittings.

3.5.8 Water Conservation

The implementation of water-savings measures may also result in energy savings, particularly in relation to hot-water usage, which can be a significant consumer of energy in a building. A simple measure that can be implemented to cut the usage volume of hot water is installing flow restrictors on taps and showers. The European water label is helpful in indicating water-efficient products.[75]

Many historic buildings, particularly those in isolated rural locations, also had systems for collecting and storing rainwater. Where old collection systems survive, it may be possible to bring them back into use as a water conservation measure, where they

[75] The European Water Label is available at: http://www.europeanwaterlabel.eu/

pose no threat to the fabric of the building from overflowing or bursting. Good building conservation practice is to avoid storing water where leaks or burst pipes could pose a threat to the building fabric.

It is important to note that any proposal to use collected grey water (wastewater from such domestic activities as clothes-washing, dish-washing and bathing) within the building or in appliances should be based on expert advice. Useful guidance on the use of collected greywater and harvested rainwater is included in TGD H.

Chapter 4

Low-Carbon Heating and Renewable Energy Sources

This chapter discusses:

- an introduction of management systems to assess the environmental and energy performance of a building.
- how to accommodate changes to mechanical and electrical systems and location of plan
- how to supplement energy usage with low-carbon and renewable sources of energy
- how to deal with existing heating systems such as plumbed heating systems and open fires
- factors to consider when choosing a heating system that is appropriate for different building types and needs

Treatment of existing heating systems is an important aspect of considering new systems. Suitably qualified professionals should be engaged before proceeding with any change to a heating or electrical system (see Chapter 1).

As outlined in TGD L, unless exempted, any building undergoing a 'major renovation' should be brought up to the cost-optimal level (see Section 1.3.3).

The potential to improve the fabric of traditional buildings may sometimes be limited due to technical, regulatory or other reasons. In those cases, the generation of energy from on-site renewable sources may be an important means to decarbonise traditional buildings.

Besides reducing users' energy bills and increasing user comfort and wellbeing, these systems can improve the energy rating of a building.

4.1 Dealing with Existing Heating Systems

Knowing how the various elements of the existing system operate is fundamental to planning the improvement of the heating system, and starts with a survey of the system and the user interaction with it.

Key questions that should be addressed include:

- Are any parts of the existing system of special interest and capable of reuse (e.g. cast-iron radiators)?
- Does the system currently consume fossil fuels (oil/gas/coal/peat) and how will the transition to zero-carbon energy sources by 2050 be managed?
- Can the fabric of the building be improved to reduce heat losses and widen the choice of suitable heating solutions – to include, for example, a heat pump that can deliver several units of heat per unit of electricity it consumes?
- Can new low-carbon heat generators be incorporated into the existing heat distribution infrastructure?
- What is the remaining operational life of the existing heating infrastructure?
- What changes to the heating infrastructure (e.g. zoning, radiator sizing, circulation pump replacement) will be required for the new heating system?
- How thermally efficient is the existing infrastructure (e.g. pipework) and can this be improved?
- How does the existing system interact with ventilation in the building, and how will the new system change that interaction?
- What space does the existing system take up, and how will this compare to the space needed for any new equipment?
- Can the risks posed to traditional buildings from fire and flood be mitigated by correct specification of any new heating infrastructure?

4.2 General Considerations when Choosing an Appropriate Energy System

Traditional energy systems such as open fires or early heating systems, while often well designed at the time of construction, are rarely an optimal solution to continue with when upgrading a building for energy efficiency. They tend to be much less efficient than modern systems and are often more environmentally damaging. When upgrading for energy efficiency, the heat source is usually paramount to energy consumption and in determining the total emissions from the building.

The Intergovernmental Panel on Climate Change (IPCC) notes that because of the complex interactions of the phenomenon of climate change, it is essential to decarbonise urgently, and that emissions reductions over the next 10 years will be crucially important to mitigating climate change. It is therefore essential to transition to energy systems that offer the largest possible energy savings and emissions reductions over that period. Generous government supports are available now to assist owners in making this transition.[76]

Capital costs and running costs remain a consideration across any project. It is not within the scope of this guidance to analyse fully costs of all systems. In general, energy-efficient systems are currently more expensive to install but have lower running costs and increased occupier comfort, and tend to increase building values. Detailed technical analysis, financial optimisation and system design are not addressed here, as there is ample literature elsewhere on these topics.

4.2.1 Heritage Considerations

The integration of heating systems within traditional buildings should be carefully considered and the works associated with installation/upgrading should not irreparably damage the historic building fabric or undermine the building's character. When striking a balance between the potential impact of low-carbon heating systems on traditional buildings and their wider carbon mitigation benefits, the following factors should be considered:

- Does the proposed system suit the particular building and use?
- Can the technology be installed safely without a significant adverse impact on the building and its historic fabric?
- Are any of the proposed changes to the building likely to have an impact on its historic fabric?
- Can reversibility be incorporated into the installation?
- What will be the visual impact of the installation on the setting of the building?
- Are there planning considerations relevant to the choice and/or positioning of equipment?

The treatment of existing redundant open fireplaces should be carefully considered. Fireplaces, gratings and surrounds may be of architectural or historic significance and may need to be retained to conserve the character of the building. Decommissioned chimneys may present an additional maintenance burden when the heat and ventilation that were present are removed (see Section 3.4.2.4 above).

Fundamental to the choice of heating system and distribution infrastructure is the fabric intervention that may be necessary to install or modify the pipe network, and how this can be minimised. Detailed consideration of the routing of any proposed pipework will be required during the design and planning process. For example, identifying the joist locations and direction of span will assist specifiers in coordinating building services with a view to designing-out unnecessary notching, thereby avoiding long-term damage to the building fabric and/or undermining of its structural stability.

Conservation best practice and structural considerations generally advise against notching original joists in traditional buildings. The material impact of any notching necessary will be assessed by the local authority's architectural conservation officer when deciding on the overall impact of such system modifications on protected structures. In cases where joist notching is absolutely necessary, and is considered an acceptable intervention, guidance on correct practice can be found in I.S. 440:2009+A1:2014.

[76] SEAI Home Energy Grants: https://www.seai.ie/grants/home-energy-grants/

The use of heating manifolds can be beneficial from this perspective as they allow for smaller diameter pipework to be used within the voids, thereby reducing fabric intervention. They also provide independent flow and return circuits to individual radiators, making control of their energy requirement much easier. The use of manifolds also provides for zoning the system. Zoning is particularly useful in areas of traditional buildings that are seldom occupied, so that when not in use, the room temperature can be reduced to an appropriate fabric protection temperature, while other occupied areas can be heated to standard heating set point. Proper zoning acts as an energy-efficiency measure and reduces overall energy consumption as a result.

Consideration of the equipment space requirements prior to detailed specification of systems is also recommended. Each system will have differing, quite specific requirements and the existing service routes should be utilised and appropriately integrated into the design.

Any new heating systems or wholescale upgrading of existing systems may not constitute exempted development in relation to protected structures and may require planning permission.

4.2.2 Choosing the Appropriate Energy System for a Traditional Building

Carbon emissions vary between fuel types, and are typically measured in grams of carbon dioxide per kWh of energy used (gCO_2/kWh). The emissions for most fuel types remain static over time. However, those for electricity will reduce dramatically as the grid is decarbonised by renewable electricity and those for gas will reduce marginally as biogas, synthgas and possibly green hydrogen are introduced into the gas network.

The emissions (CO_2 only) associated with fuel types commonly used in traditional buildings are given in Table 12.

Table 12: Carbon-dioxide emissions by fuel type

Fuel	Emissions gCO_2/kWh
Wood logs	25
Woodchips/pellets	25
Biomass or biogas	25
Biodiesel from renewable sources only	47
Bioethanol from renewable sources only	64
Mains gas	203
Electricity	224*
LPG (propane or butane)	232
Heating oil	272
House coal/anthracite	361
Solid multi-fuel	369
Sod peat	375
Manufactured smokeless fuel	392

Source: Simplified Table 8 from DEAP Manual Version 4.2.3 (November 2022): https://www.seai.ie/publications/DEAP_Manual.pdf

*SEAI: Derivation of Primary Energy and CO_2 Factors for Electricity in DEAP and NEAP 2023: https://www.seai.ie/home-energy/building-energy-rating-ber/support-for-ber-assessors/software/deap/BER-Elec-Factors-Update-2023.pdf

The electricity grid has experienced significant decarbonisation in recent years, with approximately 40% of current electricity coming from renewable sources. This is set to increase to 80% by 2030, which will approximately halve emissions from electricity, making it one of the lowest carbon energy sources. Electric heat pumps are typically three times more efficient than electric heaters, so the carbon emissions per kW of heat are three times less. Switching to a highly efficient electrical heating system (e.g. using a heat pump) therefore offers the most effective pathway to decarbonisation of space heating and hot water over the medium term. Heat pumps are the preferred solution where possible. A range of government grants and supports to facilitate switching to a heat pump are available from the SEAI.

At present, natural gas represents lower emissions per kWh than electricity; however, with the increasing utilisation of renewable sources for grid electricity production, this picture will have reversed by 2030. Furthermore, natural gas is a fossil fuel and it is national policy to phase out fossil fuel combustion.

Government policy under successive Climate Action Plans commits to phase out fossil fuel heating systems in all buildings.

4.2.2.1 Heat Pumps

A heat pump is an electrical device that is utilised to transfer heat energy from a heat source (air, ground or water) to the internal space of a building.

To determine whether a building is suitable for heating using a heat pump, the building's Heat Loss Indicator (HLI) is calculated. This measures how energy-efficient the existing building fabric is. Where an HLI is below a specified threshold, a heat pump will be suitable. Above this value, the heat pump may be too expensive to run. For many buildings, including traditional buildings, utilising a heat pump will often necessitate improvements to the building fabric – roof, floor and /or wall insulation, window and door upgrades, airtightness improvements, etc. – in order to improve the HLI. Guidance on determining whether such upgrades are appropriate or practicable is provided in Chapter 3. An upgrade to the heat distribution system (radiators, pipework) may also be required as heat pumps operate at a lower flow temperature than other heating systems.

There are broadly three types of heat pumps by source: air source heat pumps (ASHPs), ground source heat pumps (GSHPs) and water source heat pumps (WSHPs).

ASHPs take heat directly from the outside air and transfer it into the hot water circulated through a radiator system or fed into a hot water tank. ASHPs are typically of relatively low capital cost and offer a relatively simple install without extensive works.

Figure 63: Air source heat pump

GSHPs operate by the same principle as ASHPs but draw their heat from the ground. For this reason, they are more efficient and more stable, especially in winter when the air temperature drops significantly below ground temperature as ground temperature does not fluctuate to the same extent. GSHPs can use a horizontal collecting system (digging trenches and laying collecting tubes) or a vertical collecting system (drilling boreholes and availing of the higher ground water temperature at depth to yield better efficiency).

WSHPs may utilise ground water or surface water, which in either case may be stagnant or flowing. WSHPs are highly efficient, particularly when utilising ground water as a source, but their use is highly site-specific, requiring a suitable local body of water. Usage of ground water for heat pumps must be licensed by the EPA, and is likely to conflict with usage as drinking water.

Any ground works will need to be carefully considered and planned to minimise vibrations and disturbances through the soil, especially where a vertical borehole may be the only potential option to establish a collector. Consideration must also be given to historic gardens, or areas with a potential for sub-surface archaeology.

Heat pumps require less maintenance than their fossil fuel counterparts, but do require maintenance. Locating heat pumps in valleys between roof pitches, while beneficial in visual terms, should not result in damage to historic fabric as a result of maintenance access.

Low output for long periods is preferable over short cycle operation, which lowers energy efficiency and shortens the life of the heat pump. High-frequency cycling (multiple times per hour) is especially damaging. Heat pumps should be monitored for a period after installation to ensure they are operating as intended.

A mechanical & electrical engineer will be able to advise on the selection of an appropriate heat pump for a particular project.

4.2.3 Other Heating Options

If a heat pump has been determined not to be a feasible solution, other heating systems must then be considered. The guidance below provides information on the selection of other heating systems. Each system will result in different CO_2 emissions due to their different efficiencies. This guide aims to steer the building works specifier towards a system which fits well with the traditional building.

Electrical heating systems other than heat pumps (e.g. heating, ventilation and air-conditioning (HVAC), infrared panels, storage heaters and convection heaters), while not benefiting from the very high efficiency of heat pumps, still offer some long-term potential to decarbonise a heating system as the grid becomes less carbon-intensive. These systems may also have benefits from the perspective of capital cost, as there is no infrastructure for their usage beyond wiring, mounting and controls. For budget-limited projects, the capital uplift required to go from a low-efficiency electric solution to a heat pump might be better spent on fabric upgrades, and such fabric upgrades could subsequently facilitate installation of a heat pump.

4.2.3.1 Solid Biofuel (Biomass) Boiler

A biomass boiler uses a solid fuel combustion process to produce heat. The biomass consumed is typically wood pellets that have been sustainably sourced, making these units a greener alternative to the standard solid fuel stove. The installation of these units is most beneficial where there is an existing wet system for heat distribution in the building, as this typically allows for the old heat source (e.g. solid fuel burning, boiler stove) to simply be swapped out for the biomass boiler. A range of biomass fuels exist for use in these boilers, each having particular characteristics that will influence the choice of boiler type and the requirements for other parts of the system, such as fuel handling and storage.[77]

The fuel type used is usually determined by availability, reliability of supply and price, as well as the site characteristics, such as the heat demand to be supplied and the space available for fuel storage. Other factors to be considered are fuel handling, any local air-quality restrictions in place and accessibility for fuel delivery trucks.

Wood-burning boilers or stoves may be a viable option as part of the heating system. Wood may be considered carbon-neutral due to the carbon sequestered during the growth of trees; however, the source of biomass in all cases, including wood for burning, is important. Wood should be locally sourced from sustainable forestry in all cases and of low moisture content, but preferably should not be kiln dried. Additionally, burning wood, especially wet wood, emits high levels of particulate matter, affecting air quality inside and in the local area of the building. There are also gaseous emissions including sulphur oxides (SOx), nitrogen oxides (NOx) and carbon monoxide (CO), the emissions of which are higher when combustion occurs at lower temperatures, as in open fires. The quality standard governing certified wood fuel is ISO 17225. The Wood Fuel Quality Assurance scheme, managed and administered by the Irish Bioenergy Association (IrBEA), is a useful recognised label of certified suppliers of ISO 17225 compliant wood in Ireland.

4.2.3.2 Wood-Burning Stove with Back Boiler

In these stoves, wood (which should be sustainably sourced) is combusted to produce heat. Most of the heat produced is circulated through the radiator system in the building to provide space heating. The stove also heats the domestic hot water. A wood-burning stove has less precise temperature controls than other heating systems and must be installed and operated with care to minimise the associated fire risk. A wood-burning stove typically has high emissions of particulates, which also present a hazard to human health.

It typically requires a large storage area for fuel, which is not always practical, especially in an urban setting.

4.2.3.3 Infrared (IR) Space Heating Panels

An IR heating panel consumes electricity to emit heat in radiant form. IR heating panels do not offer the high efficiency of heat pumps; their primary advantage is in heating surfaces, people and thermal mass rather than the air in between. This can be advantageous for traditional buildings with non-continuous demand for heating, buildings without radiators and/or buildings with frequent air changes that cannot be mitigated.

IR panels have other potential benefits, including low capital cost and the ability to be mounted in a variety of locations and orientations. Ceiling-mounted panels provide focused heating to the area below them and wall-mounted panels can be positioned to heat a specific target area. This allows specifiers to avoid decorative wall or ceiling features.

As with all electrical heating systems, emissions will drop significantly when systems are used in conjunction with solar PV.

[77] Government of Ireland (2019).

4.2.3.4 Biogas Boiler

A biogas boiler operates on the same principle as a standard natural gas boiler but instead uses a fuel source obtained through the anaerobic digestion of biomass material, such as manure, agricultural waste or food waste. The installation of a biogas boiler is most advantageous in cases where there is an existing natural gas boiler and hence an existing heat distribution network that can be modified, as biogas boilers' operational temperature is comparable to fossil-fuelled boilers. This contrasts with heat pump installations, which may require heating infrastructure upgrades due to their lower operating temperature.

The IrBEA operates a register of trained designers and installers, which may be used for reference on projects considering biofuel systems.

4.2.3.5 Hydrotreated Vegetable Oil (HVO) Boilers

HVO is a biofuel, which can be produced using vegetable oils such as palm, rapeseed, sunflower or soybean. It can be used as a substitute fuel for kerosene, but may require modification of the boiler to accept the HVO product. HVO may provide lower CO_2 emissions than kerosene, depending on the source, but may be expensive.

HVO availability in Ireland is currently low and has a much higher unit cost than traditional fuels. Additionally, there is some inconsistency in the quality of HVO on offer, with only some providers being able to verify that their HVO product is sustainably sourced.

4.2.3.6 Storage Heaters with Domestic Hot Water (DHW) Immersion

Traditional night storage heaters work on the principle of slowly releasing energy from a thermal store. During the night, when electricity rates are cheaper and the emissions per kWh of electricity used are less, the storage heaters consume electricity to build up a thermal energy store, which is then slowly released throughout the following day. This operating principle is achieved using high heat capacity clay or ceramic bricks surrounded by electrical heating elements.

A newer version of this technology, known as Smart Electric Thermal Storage, is also on the market. While these units work on the same operating principle as the traditional night storage heater, they have added flexibility as the thermal store can be charged at any time to suit electrical grid conditions. These units can also be connected to a cloud aggregation platform, which issues optimised charging schedules to the appliances.

These units do not provide domestic hot water, so a separate immersion heater or solar water heating is required to heat the water in the storage cylinder. PV systems can also offset the grid electricity used.

4.2.3.7 Electrical Convection Heaters with DHW Immersion

Convection heaters consist of an electrical heating element that heats the surrounding air, causing it to rise and circulate around the room. This circulation of air creates a convection current that distributes the heat energy to the surrounding space. This unit is independent of the DHW supply, therefore an immersion heater coil or solar water heating is required to heat the water in the storage cylinder. PV panels can be used to offset the grid electricity used.

4.2.3.8 Combined Heat and Power (CHP)

A CHP system is in essence a small-scale power plant, which produces both electricity and heat. CHP may use gas, biogas, biomass (woodchip or pellet), but the fuels are not interchangeable.

CHPs are typically sized to match the entire heating demand for a building, while supplementing the electrical demand. It is important that the building has sufficient, consistent electrical demand to match the electrical output, or the ability to increase its capacity (demand response, for example though smart electric vehicle (EV) charging or diversion controllers for hot water) or to store any excess electricity produced (e.g. in batteries).

CHPs are most appropriate in cases where a heat pump is not possible, there is an existing gas supply, and there is sufficient, consistent demand for both space heating and electricity. Facilities with constant heating demands such as hotels and those with swimming pools are common candidates for CHPs.

Any CHP installation should consider the potential for long-term emission reductions in comparison to an electrical pathway, and the building works specifier should be cognisant of technological lock-in.

4.2.3.9 Open Fires

Open fires are highly inefficient heating systems, having around 30% combustion efficiency. Additionally, they require permanent vents for combustion ventilation, which further affects the thermal performance of buildings. When open fires are decommissioned, restricting the flue to prevent passive airflow will be necessary to improve the airtightness of the building.

Any room with a combustion appliance, e.g. a fireplace, must have a suitably sized permanent ventilation opening so that the free area is sufficient for the appliance installed. Where works in an existing building involve sealing up existing air infiltration pathways (e.g. gaps around windows, gaps between floorboards), such works may constitute a 'new or greater contravention' of the safe operating conditions of an existing combustion appliance. Therefore, alternative means of providing sufficient permanent ventilation may be required to protect occupants from exposure to the toxic by-products of combustion.

In energy calculations (DEAP/NEAP), every chimney is assumed to have its own vent, which is permanently open, whether the chimney is in use or not.

When technically preferable and more efficient heating systems such as heat pumps are not possible, a room-sealed wood-burning stove, with a ducted combustion air supply, may be a viable option as part of the heating system and the existing flue may be adapted accordingly. Room-sealed combustion appliances take their air from an uninhabited ventilated space within the premises or from the air outside the building through an external air vent on the rear of the appliance, and hence do not require the installation of a permanent wall vent within the room. As a result, they can deliver considerable energy savings compared to open-flued combustion appliances. Further guidance is available in TGD J.

4.2.3.10 Hydrogen Boiler

Hydrogen is a colourless, odourless, versatile gas that can be produced in a variety of ways. When produced via the electrolysis process, and using green electricity, hydrogen (known as green hydrogen) is a renewable fuel with very low emissions (comparable to the low emissions of renewable electricity). It also has no direct emissions, producing only water vapour when burned, in comparison to natural gas, which releases CO_2. In contrast, blue hydrogen is produced from natural gas with carbon capture and storage. In this instance, the CO_2 emissions generated during the manufacturing process are captured and permanently stored underground, making the process and end-product a low-carbon solution, but still not as clean or environmentally friendly as green hydrogen.

Hydrogen boilers offer the potential to switch out existing gas boilers and retain the rest of the heating infrastructure in place (if this infrastructure is in good condition).

At present, hydrogen boilers are in their infancy, with high appliance costs. Additionally, there is currently no readily available commercial green hydrogen with which to supply these units. Natural gas has the advantage of the existing gas network, while the future distribution system of green hydrogen in Ireland is currently unclear – it may have a dedicated distribution network, be blended with and then extracted from the gas network or be supplied in bottled form.

Hydrogen combustion in boilers offers a pathway to the decarbonisation of heating that may become practical in the coming years.

4.2.3.11 Multi-Source Heating Systems

While the heating source technologies listed above have been detailed in the context of single-source systems, that does not mean that they can only be utilised or installed in that way.

Figure 64: Sample Georgian townhouse used in district heating connection example

Some of these technologies can be combined to form a multi-source heating system so that they complement and work in tandem with one another. For example, a biomass boiler could be used as the primary heating source with storage heaters as the secondary heating source, or installed separately to provide heating to a particular heating zone. This combination or a similar one can be beneficial where the heating zone supplied by the storage heaters is seldom occupied and may only need to be maintained at a level temperature during unoccupied periods to avoid thermal shock or fabric degradation.

4.2.3.12 District Heating

In a district heating network, heat is generated at centralised locations, and distributed (via insulated pipework) to each property connected to the network. A heat exchanger at each building transfers the heat energy from the district-heating network to the building's own water-based heating system.

Once a district heating system is established, it is possible to connect many sources of heat, for example waste heat recovery from power stations and industrial sites, biomass boilers, biomass combined heat and power, air source heat pumps, ground source heat pumps, and low-carbon gas CHP.

Ireland currently has only a few small-scale district heating networks; however, the SEAI National Heat Study[78] suggests that district heating networks could provide as much as 50% of the built environment's heat demand in Ireland in the future. The District Heating Steering Group Report[79] will inform the future delivery of district heating in Ireland.

[78] Government of Ireland (2022)

[79] Government of Ireland (2023b)

Connecting a Traditional Building to District Heating

Government policy has highlighted that district heating could be a major heat source for dwellings and businesses in the coming years to help Ireland meet its climate targets.

This example illustrates the effect of connecting a traditional building to an efficient district heating system[80] using waste heat as the main heat source.

The four-storey-over-basement Georgian townhouse is occupied as a single-family dwelling. The home is heated with a central gas boiler and has six open fireplaces.

The BER before connection to district heating is D2 with CO_2 emissions of 55 $kgCO_2/m^2$. After connection to the Dublin District Heating System (DDHS), the BER improves to C1 with lower CO_2 emissions of 27 $kgCO_2/m^2$.

District heating can be provided by a two-pipe system into the dwelling. A structural survey is needed when boring holes into the external fabric or laying pipework in the surrounding areas of the dwelling to prevent damage to the property's structural intent. In the case of protected structures or buildings in an ACA, an architectural heritage impact assessment of the works may also be required.

In most cases, the district pipework brought into the dwelling will terminate in a heating interface unit (HIU). The HIU is similar in size to a traditional fossil fuel gas boiler. It delivers heat to the space heating pipework/radiators and to all hot-water appliances such as wash-hand basins, baths, showers and sinks. The space heating controls are similar to a traditional heating system with a thermostat and timing programmer.

Some modification to the existing heating and water pipework within the dwelling may be required and some equipment, such as the hot-water cylinder, may be removed altogether as the district heating system provides instantaneous hot water to the dwelling through the HIU.

Generally, charging is based on the heat consumed and the HIU contains a heat meter that can tabulate the amount of heat used in the dwelling for billing purposes.

4.3 Renewable Energy and Traditional Buildings

In traditional buildings, where fabric upgrade measures can sometimes be limited by the character of the building, renewable energy systems can be a useful means to decarbonise and may offer a viable pathway to a BER of B2 or better.

Renewable energy may supply electricity, space heating, hot water or some combination of the three. Each of these is discussed below.

In buildings, the heat load may be separated into the space heating demand and the water heating demand. These loads may be provided by the same system or by different systems in any given building. A renewable or low-carbon energy

[80] See https://www.dublincity.ie/residential/environment/dublin-district-heating-system for more information

system supplying a heat demand may tie into the existing system or replace it entirely.

Renewables that generate electricity are rapidly gaining in popularity due to the high value of each unit of electricity generated. 'Behind the meter' systems that supply a building or group of buildings directly are particularly good investments, as they are reducing grid electricity usage, the most expensive form of energy per kWh. Buildings whose occupants currently pay a high cost per kWh for their electricity will find these technologies to be particularly viable, and the savings from investments in these measures may offset the costs of other upgrades.

The following factors should be considered when assessing the suitability of solar energy systems.

- Will the installation avoid any irreversible alteration to the historic fabric?
- Can any adverse impacts be mitigated?
- Is there safe access for maintenance or can a safe access strategy be developed?
- Can the solar collectors be located on roof slopes not visible in important views of the building?

If the answer to all the above questions is positive, the designer may proceed to a technical evaluation of the appropriate system.

Where an installation would impact on the character of a protected structure, or a building located in an ACA, early consultation with the local authority architectural conservation officer is recommended.

Solar PV and solar thermal systems are generally not suitable for installation on thatch roofs due to the elevated fire risk. Stone slated roofs may also present insurmountable technical fixing issues for solar systems. In these cases, consideration should be given to locating the systems on outbuildings or extensions.

Further information and guidance regarding the design, installation, commissioning and maintenance of solar PV systems is available in S.R. 55:2021 - *Solar Photovoltaic Micro-Generators for Dwellings – Design, Installation, Commissioning and Maintenance*, available from NSAI.

Key considerations for installations undertaken in traditional buildings should be minimal intervention and reversibility. Other factors include, but are not limited to, the load-bearing capability of the overall roof structure, the fragility of the roof covering and any increased access with the potential to damage the existing roof finish. If historic slates or tiles are removed to facilitate the installation, these should be safely stored for future reuse.

Where no appropriate rooftop space is available for mounting PV systems, ground-mounting may be considered.

When seeking to improve the BER rating, a sympathetically designed and appropriately installed solar energy system can be used to offset the requirement for more intrusive fabric interventions, which may not be appropriate in some traditional buildings.

4.3.1 Solar PV

Solar PV is a mature, effective and low-impact technology, which provides green electricity directly on site. The rapid decrease in the cost of PV systems in recent years means that they are now in most cases a sensible financial investment, as well as a useful measure to reduce primary energy consumption and its associated emissions.

Solar PV systems in Ireland do not usually require excessive cleaning due to the rainy environment, but some cleaning is recommended to maintain high performance. In some instances, access for


Figure 65: PV on the rear roof pitch of a traditional building


Figure 66: PV on the front roof pitch of a traditional building


Figure 67: PV on the roof of an outbuilding

cleaning may present a challenge; for example, on roofs that are not easily accessible or where damage can occur to traditional roof coverings.

PVs will be able to export unused power to the grid and receive a tariff, but this will never be as economical as on-site consumption. On-site battery storage can allow excess energy produced in the daytime to be stored for use at other periods. Elsewhere, excess renewable electricity can be stored as hot water, which can be a more economical option than using a battery.

4.3.2 Wind Turbines

Wind turbines function best at large scales and require airflow that has both high velocity and low turbulence. Additionally, turbines create vibration, and must be carefully located away from buildings to avoid the impacts of noise, vibration and flicker. For these reasons, their potential for contribution to direct energy provision to the built environment, and to traditional buildings in particular, is very limited.

4.3.3 Hydropower Turbines

Improvements in small turbines and generator technology mean that 'micro' technology (under 100kW) hydro schemes are an attractive means of producing electricity. As a result, much focus nowadays is on small developments. The likely range is from a few hundred watts (possible for use with batteries) for domestic schemes to a minimum of 250kW for commercial schemes. Another option is to refurbish old buildings (e.g. water mills) to generate electricity.[81]

4.3.4 Solar Thermal

Solar thermal collectors, or solar hot water collectors, are devices that capture solar energy and transfer it to heat water.

Figure 68: Disused gravity fed water channel for a hydro scheme

The amount of water supplied by solar thermal collectors depends on the system size and building hot water demand. Typical well-installed systems can provide up to 60% of domestic hot water demand over 12 months. There are two general types of solar thermal collectors: flat plate collectors and evacuated tube collectors.

The rapid decrease in the cost of PV systems and their lower maintenance demands has resulted in a decrease in the popularity of solar thermal systems.

[81] For further information see: Small Scale Hydro Generation, Teagasc – the Agriculture and Food Development Authority: https://www.teagasc.ie/rural-economy/rural-development/diversification/small-scale-hydro-generation/ and SEAI Hydro Power Map: https://www.seai.ie/technologies/seai-maps/hydro-power-map/

4.4 Renewable Energy Supply

Directly reducing energy consumption should always be the first consideration of any project. In tandem with this, consideration should be given to the appropriate low-carbon or renewable heating system and the appropriate options outlined elsewhere in this document.

Decarbonisation of both the electrical and gas networks is currently underway and is being progressed by the integration of green energy sources with these networks. The electricity network has experienced the greatest shift towards a greener future as electricity providers now seek to procure their electricity through green energy sources only. Decarbonisation of the gas network, while underway, has further to go in comparison to the electricity network. Green energy sources such as biomethane and green hydrogen offer pathways towards this decarbonisation initiative but entail high production costs and experience low production volumes at the time of writing. When considering biofuels in general, the sustainability of their source is an essential consideration. Ideally, they should be local and/or created from waste products.

The National Heat Study completed an extensive analysis of bioenergy resources in Ireland and identified biomethane is a competitive, cost-efficient path to decarbonising sectors with a high thermal heat demand. Biomethane as a renewable gas source is also becoming increasingly important in terms of security of supply, and government has committed to the production of 5.7TWh of indigenous biomethane by 2030.

Regardless of how energy is sourced in the future, sustainability must remain a key consideration to avoid negative impacts on land use and food security.

4.5 Services Infrastructure and Space for Plant

Before proceeding to choose the correct heating system for a building, it is important to be cognisant of the condition of the existing infrastructure, and to consider the requirements for plant and plant location for the system that will be installed.

In general, the distribution infrastructure should be considered when looking at new heating systems, especially when fabric works are being undertaken. It is then crucial that the heating infrastructure is considered in the planning and design process to ensure that opening-up works are optimised. This reduces the potential visual and physical impacts of any pipework to be installed.

In addition to the plumbing infrastructure, the electrical infrastructure may need to be upgraded to support the functioning of a new heating system. This is particularly true where the electrical infrastructure is ageing, and where the new heating system has a large power demand.

The cumulative impact of successive rewiring and replumbing actions can be highly, and irreversibly, damaging to traditional building fabric and should be carefully considered at the design stage.

List of Figures

List of Tables

List of Abbreviations

ACA	Architectural Conservation Area
ACM	Asbestos-Containing Material
ASHP	Air Source Heat Pump
BER	Building Energy Rating
BRP	Building Renovation Passport
CE	Conformité Europèene
CHP	Combined Heat and Power
CO_2eq	Carbon Dioxide Equivalent
DEAP	Dwelling Energy Assessment Procedure
DHW	Domestic Hot Water
EED	Energy Efficiency Directive
EPA	Environmental Protection Agency
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate or Coefficient
EPD	Environmental Product Declaration
EU	European Union
EWI	External Wall Insulation
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
GWP	Global Warming Potential
HIU	Heating Interface Unit
HLI	Heat Loss Indicator
HSA	Health and Safety Authority
HVAC	Heating, Ventilation and Air Conditioning
HVO	Hydrotreated Vegetable Oil
IAQ	Indoor Air Quality

IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
IrBEA	Irish Bioenergy Association
IWI	Internal Wall Insulation
LCA	Life Cycle Assessment
LED	Light Emitting Diode
LENI	Lighting Energy Numeric Indicator
LPG	Liquefied Petroleum Gas
M&E	Mechanical and Electrical
NEAP	Non-Dwelling Energy Assessment Procedure
NSAI	National Standards Authority of Ireland
PIR	Polyisocyanurate
PM	Particulate Matter
PV	Photovoltaic
RIAI	Royal Institute of the Architects of Ireland
RMP	Record of Monuments and Places
RPS	Record of Protected Structures
SCSI	Society of Chartered Surveyors Ireland
SEAI	Sustainable Energy Authority of Ireland
TGD	Technical Guidance Document
VCL	Vapour Control Layer
VOC	Volatile Organic Compound
WSHP	Water Source Heat Pump


Scoil Naoṁ Íde
Áṫ na Fuinnseoige
Scoil Náisiúnta
ASHFORD GIRLS' N.S.
A.D. 1931.

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Appendix II: Further resources

Historic England:

https://historicengland.org.uk/advice/technical-advice/retrofit-and-energy-efficiency-in-historic-buildings/

Historic Environment Scotland:

Refurbishment Case Studies, available at: https://www.historicenvironment.scot/about-us/what-we-do/conservation/refurbishment-case-studies/

Technical Papers, available at: https://www.historicenvironment.scot/archives-and-research/our-research/

Sustainable Traditional Buildings Alliance:

https://stbauk.org/stba-research/

Appendix III: Development Team

This guidance was developed by a Project Steering Group set up by the Department of Housing, Local Government and Heritage to implement Action BE/23/15/B of the Climate Action Plan 2023. The Project Steering Group comprised representatives of the Department of Housing, Local Government and Heritage; the Department of Environment, Climate and Communications; the Department of Education; the Office of Public Works; the Heritage Council; and the Sustainable Energy Authority of Ireland, as follows:

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